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THE GREAT LAKES BOTANIST

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PLANTS OF THE CHICAGO REGION
Gerould Wilhelm & Laura Rericha
Flora of the Chicago Region
A Floristic and Ecological Synthesis
FLORA OF THE INDIANA DUNES
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PLANTS of the CHICAGO REGION
GUIDE

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IN THIS ISSUE

The first article in this issue is the third installment in a project to update Emma Cole's 1901 *Grand Rapids Flora* and re-examine the present state of the flora and the vegetation of the flora area. The current article examines several natural areas in the greater Grand Rapids area that were explored by Emma Cole to evaluate floristic changes in each area since the 1890s. In the course of this study, several new records for the flora area were documented.

The second article, one of a series of student research projects at Purdue University Fort Wayne in northeastern Indiana, examines the effects of size, shape, and relative isolation, as well as several environmental factors on the diversity and richness of several small forest fragments surrounded by agricultural land.

The problem of invasive species is increasingly problematic, and therefore studies of this phenomenon are valuable. Katherine Moesker examines in detail the biology of an Asian species of *Magnolia* that has become established in natural areas of the Royal Botanical Garden in Hamilton, Ontario, and discusses the factors that permit invasion by alien plants into a natural area, as well as characteristics of potential invasives.

The next article examines a method of managing invasives, in this case on the Menominee tribal lands in northern Wisconsin. The method involves washing vehicles before entering onto the land to be protected. In addition to reporting on the effectiveness of this method, best practices for use of this method are set forth.

This issue contains three reports of new records in the Great Lakes area: the first report for Ontario of the ophioglossoid fern, *Botrychium mormo*, in the Thunder Bar region of northwestern Ontario, a green alga reported for the first time from North America, and new records of four species of grasses that are either rare in, or reported for the first time from, Wisconsin.

Neil Harriman, who was editor of *The Michigan Botanist* (the predecessor of this journal) from 1998 to 2005, passed away in December of last year as the most recent issue of *The Great Lakes Botanist* was going to press. One of his students, Thomas Eddy (also an occasional contributor to this journal), has prepared a brief article recounting Dr. Harriman's life and career and that includes a list of his published articles.

Two books covering plants in the Great Lakes area are reviewed in this issue. Early 2017 saw the publication of the comprehensive and long-awaited *Flora of the Chicago Region* by Gerould Wilhelm and Laura Rericha, which is a worthy successor to a long line of previous floras covering that area. In addition to a detailed examination of the new volume, the review recounts the interesting history of floristic publications covering the Chicago Region to place the new work in its historical context. The second review discusses a new book covering the sedges and rushes of Minnesota by Welby Smith, who has also written previous manuals covering the orchids and the trees and shrubs of Minnesota.

—Michael Huft

FLORISTIC QUALITY ASSESSMENTS OF REMNANT NATURAL AREAS IN THE GREATER GRAND RAPIDS, MICHIGAN REGION: EVALUATING BOTANICAL CHANGE SINCE THE 1890s

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ABSTRACT

In 1901, Emma J. Cole, a beloved high school teacher and distinguished botanist, published *Grand Rapids Flora*. Cole's floristic inventory remains the most comprehensive botanical study of the greater Grand Rapids, Michigan region, even though this area has experienced significant landscape alterations since her publication. To address this knowledge gap, in 2014 we embarked on a multiple-year project aimed to discover and reassess the sites Cole described, as well as to catalog other natural remnant locations within the Grand Rapids area. This paper reports botanical inventories that were completed at eight sites within Kent County during 2015 and 2016. Plants were documented by herbarium specimens and sight records. A Floristic Quality Index (FQI) was generated for each site. Overall, 980 specimens were collected from these 8 sites, including 20 new Kent County records and 4 state-listed species. At two localities, sufficient herbarium specimens collected by Cole and her students from the 1890s allowed for direct site comparisons using FQIs and Simple Matching Indices. At Mill Creek Woods, a rich deciduous forest, comparing the 1895–96 and 2015–2016 FQI values shows that the floristic integrity of the area has decreased, but not as dramatically as might be expected over the past 120 years. At Soldiers' Home Woods, also a deciduous forest, the overall size of the habitat had shrunk due to urban expansion, but the FQI comparison of the 1890s and 2015–2016 indicated only a slight drop in native species richness, yet also an increase of adventive species. Simple Matching Indices comparing both historic sites to today were above the similarity threshold, indicating that at the community level these habitats have not deviated significantly over the years.

KEYWORDS: Michigan Flora, Biodiversity, Historical Botany, Emma Cole, Floristic Quality Assessment.

INTRODUCTION

In 1901 Emma Cole published *Grand Rapids Flora: A catalogue of the flowering plants and ferns growing without cultivation in the vicinity of Grand Rapids, Michigan* (Cole 1901). Cole's remarkably fine *Flora* provides a valuable window into the natural landscape of the Grand Rapids region during the late 1800s. Her account also helps bring into focus the biodiversity costs of development and urban expansion that have occurred in the Grand Rapids region over the past century.

Although native peoples had occupied the southwestern Michigan landscape for over 10,000 years, significant land alteration did not begin until the mid- to late-1800s. Grand Rapids itself was initially settled by Euro-Americans as a mis-

sion station to the Ottawa people in 1825 (Goss 1906), and Louis Campau established a trading post and blacksmith shop there the following year. After being established as a village in 1839, Grand Rapids was incorporated as a city in 1850, with an initial population of 2,686 occupying 4 square miles of Walker and Grand Rapids Townships (Lydens 1966). By the time Emma Cole began teaching at Central High School in 1881 (Stivers 2007; Stivers and Crow 2018), Grand Rapids had swelled to approximately 11 square miles, with a population of more than 32,000, which increased to more than 87,500 by the time Cole's *Flora* was published in 1901 (Lydens 1966).

Situated on the Grand River, Michigan's largest river, Grand Rapids developed into a major center of commerce in the state. In addition, with the establishment of the Kent Scientific Institute, it was also highly regarded for its scientific contributions (Baxter 1891). Emma Cole significantly advanced the botanical pursuits of the Institute, serving as head of its Botany Department. She also organized the Grand Rapids Botanical Club, and through these various roles, including her teaching, she mentored many young people. Emma ultimately became vice-president of the Kent Scientific Institute in 1900 (Stivers 2007; Crow 2017; Stivers and Crow 2018).

Even as Emma Cole was doing her fieldwork in the late 1890s, she was already lamenting the significant botanical changes taking place in the region due to expanding urban and agricultural development, including the loss of the last 3-foot diameter Hemlock trees (*Tsuga canadensis*) from the Burton Avenue Swamp (which was later drained), ". . . whose annual rings show[ed] them to be 250–300 years old . . ." (Cole 1901). She recorded 176 non-native species, most of which were introduced from the Old World and several of which turned out to be first records for the State of Michigan. Among these were such weeds as the noxious Cheat Grass (*Bromus tectorum*) and the widely distributed tumbleweed, Winged Pigweed (*Cycloloma atriplicifolium*). She also recounts several non-native species first showing up on a farm in Paris Township where waste from the Felt-Boot Factory was used as fertilizer; the wool (inadvertently carrying seeds) was imported from western states (Cole 1901, Crow 2017).

The area of study (585 square miles) covered by Cole's *Flora* (which she referred to as the "district") encompassed 16 townships centered on the city of Grand Rapids. It also had one small extension of 3 sections (9 square miles) eastward into Vergennes Township, which included her childhood home where she made numerous collections (Figure 1).

The work reported here is part of a multi-year project, the goal of which is to rediscover and inventory the collecting localities that were visited by Emma Cole (as well as her colleagues and students) and also to catalog other high-quality natural community remnants in the Grand Rapids region. Cole's work was well-documented with many herbarium specimens, most of which still exist today in herbaria at the University of Michigan (MICH), Michigan State University (MSC), Albion College (ALBC), and others. Crow (2017) brought the nomenclature of plants enumerated in Cole's *Flora* up to date, so that comparisons can be made more easily with today's flora, and also cited all the specimens that documented her *Flora*.

Here we report data from eight sites that were inventoried during our 2016

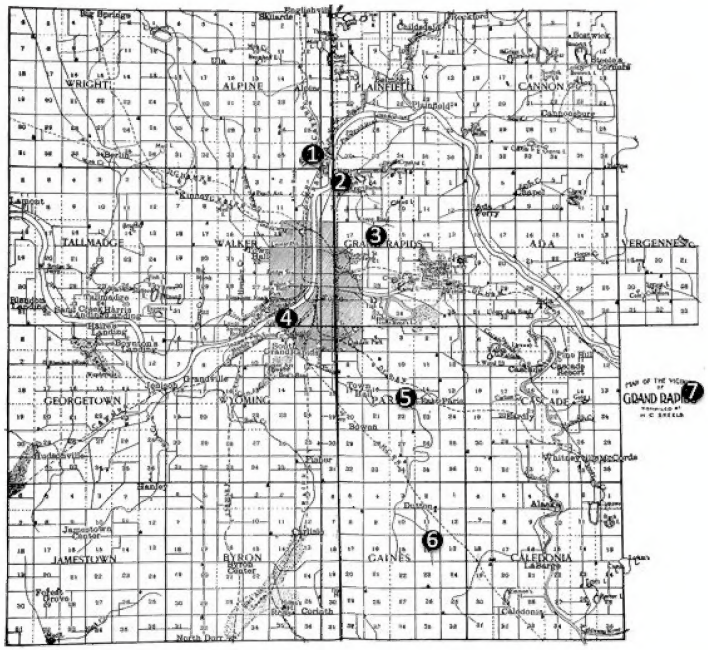

FIGURE 1. Map from Emma Cole's *Grand Rapids Flora* (1901). The location of the study sites are indicated by numbered circles as follows: (1) Mill Creek Woods; (2) Soldiers' Home; (3) Mr. Lowes' Woods; (4) Black Hills; (5) Paris Park; (6) Shadyside Park; (7) B.D. White Preserve (to the east off the map).

fieldwork: Mill Creek Woods, Soldiers' Home Woods, Paris Park, Black Hills, Mr. Lowes' Woods, Shadyside Park, and two separate habitats from the Bradford Dickinson White Nature Preserve. Data for the first five localities include collections made both in 2016 (by the authors and Lydia Abma) and in 2015 (by Dorthea Leisman, Emily Van Staalduinen, Garrett Crow, and David Warners). Inventories of Shadyside Park and a Dry Southern Forest and a Southern Shrub-Carr Wetland in the Bradford Dickinson White Preserve were compiled from 2016 fieldwork only.

We made direct historical comparisons of two sites based on information from Cole's *Flora* and lists of species generated from extant specimens collected at those localities in the 1890s. These sites are 1) Mill Creek Woods in Comstock Park (Alpine Township), and 2) Soldier's Home Woods, then in Grand Rapids Township but now incorporated within the City limits of Grand Rapids. Both these sites were "favorite" collecting places and received frequent visits from Cole and/or her students and colleagues, including a visit by C. F. Wheeler of Michigan Agricultural College, a co-author with W. J. Beal of the 1893 version of *Michigan Flora* (Beal and Wheeler 1893).

Historic botanical studies like Emma Cole's remarkable work, provide ex-

tremely valuable reference points for present-day ecological studies (Higgs et al. 2014). These descriptions or lists allow for an assessment of what elements of the local flora have been retained and which have been lost. By comparing with present day inventories, they also highlight particularly noteworthy remnant communities, offer a baseline for ecosystem health, and can help prioritize preservation and restoration efforts.

METHODS AND MATERIALS

Study Sites

Five locations were inventoried in both 2015 and 2016, and two locations, one of which had two distinct sites, were inventoried only in 2016. These sites were chosen either for their historical significance in relation to the work of Emma Cole and her colleagues or because they appeared to retain significant pre-European settlement habitat (Figure 1).

Mill Creek Woods (43° 2.365′N, 85° 40.440′W; 43° 2.632′N, 85° 40.230′W):

Emma Cole's *Flora* describes a site referred to as "The Mill Creek Woods" (Figure 1, site 1). In the 1890s, it was located northwest of the old West Michigan Fairgrounds and consisted of a series of wooded hills that were intersected by ravines and creeks (Cole 1901). This was a favorite collecting spot of former Cole students, Homer Skeels and Jennie Shaddick, who collected numerous specimens over the 3-year period of 1895–1897. Cole (1901) noted that it was largely woods of White Pine (*Pinus strobus*), with birch (*Betula* sp.), maple (*Acer* spp.), and an occasional Tulip-tree (*Liriodendron tulipifera*) (Figure 2); the overall flora suggested a northern character. Today, a fairly large remnant of woods is still present (11.4 ha) along Mill Creek upstream of Dwight Lydel Park, Comstock Park (within Alpine Township), including ravines and bluffs adjacent to railroad tracks and the woods lying north and south of the railroad crossing at Lamoreaux Drive NW.

Soldiers' Home Woods (43° 0.860′N, 85° 39.680′W):

This deciduous woods is located on the south side of the present-day Grand Rapids Home for Veterans on Monroe Street, just east of the Grand River at Riverside Park, Grand Rapids (Figure 1, site 2). The Soldiers' Home was originally constructed in 1886 for veterans in the aftermath of the Civil War (Lydens 1966; Grand Rapids Home for Veterans 2015). The adjacent forested area was visited by Emma Cole and her colleagues during the 1890s, as evidenced by numerous extant collections. Today, the woods are bordered on the south by 4-Mile Road, by housing development to the east, by park-like lawn with large trees on the west, and by the Veterans' Home on the north. A portion of the woods adjacent to the Veterans' Home includes a fenced-in nature area with a handicap-accessible path for residing veterans.

Lamberton Creek flows through the historic Soldiers' Home property and into the Grand River, with numerous specimens from the 1890s specifically collected in the woods near its mouth. A remnant of this woods exists today at the northernmost part of Riverside Park, just west of Monroe Avenue NE and the present-day Veterans Cemetery at the Grand Rapids Home for Veterans, and south of the I-96 overpass (43° 1.185′N, 85° 39.690′W). Although slightly disjunct today from the Soldiers' Home Woods described above, data for the woods along Lamberton Creek were combined with data for Soldiers' Home Woods, since herbarium labels suggest these two parcels were part of a contiguous forest in the 1890s (i.e. "Lamberton Creek Mouth, Soldiers' Woods" and "Soldiers' Home toward Grand River"). The current composition and age structure of trees is also similar in the two locations, adding further support for their previous connectivity.

Mr. Lowes' Woods (42° 59.589′N, 85° 37.591′W):

Occasionally, Cole (1901) referenced the "woods of Mr. Lowes, Section 16, Grand Rapids [Township]." Correlating Emma Cole's comments with a 1938 aerial photograph allowed us to confidently surmise that this site is a wooded ravine that has never been cleared (Figure 1, site 3). Pinpointing the locality on Google Earth satellite images revealed that a large portion of Section 16 has become re-forested today via secondary succession (Figure 3). Site visits confirmed that the forested

FIGURE 2. Tulip Tree (*Liriodendron tulipifera*) flanked by Lydia Abma and Alan Stockdale in Mill Creek Woods, Comstock Park (Alpine Township), Michigan. Photo 2016, by Garrett Crow.

ravine, property owned by Berkeley Hills Church, is much more mature than surrounding woodlands, most of which constitutes a city-owned property known as Ball-Perkins Park, situated between Knapp and Leonard Streets NE, and Ball and Perkins Avenues NE. The southwest portion of the Ball-Perkins Park property is occupied by an old farm pond. Concept plans exist for future development of this city-owned parcel into a large urban park (Friends of Grand Rapids Parks 2017), and some trail construction has already begun.

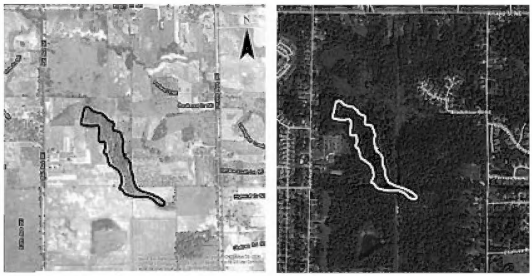

FIGURE 3. Aerial photographs showing section 16, Grand Rapids Township (now incorporated into the City of Grand Rapids). The outlined portion signifies Mr. Lowes' Woods in 1938 (left), (image: 1938; source: Michigan State University Remote Sensing & GIS Aerial Imagery Archive), versus the current landscape (right), (image: 7/30/2018, source: Google).

Black Hills (42° 56.622′N, 85° 41.500′W):

The Black Hills area consists of a wide plateau overlooking the Grand River approximately 1 mile southeast of downtown Grand Rapids (Figure 1, site 4). This former "island" in the Grand River floodplain is situated on the north side of Plaster Creek, just before it enters the Grand River. It is easily accessed via Hall Street SW, ca. 1 mile west of U.S. 131. It is known as the location of the summer village of Chief Blackbird (Mack-e-bee-messy), of the Ottawa tribe; a grove of Black Oak (*Quercus velutina*) covered the hills, giving it the name Black Oak Hills, which was ultimately shortened to Black Hills (Belknap 1922). During Emma Cole's day, the Black Hills also overlooked expansive rail yards, factories, and shops, with the Pere Marquette railroad tracks running along the base of the Black Hills (Belknap 1922).

Today, the hill is occupied by a residential neighborhood and an abandoned elementary school, with a major power line right-of-way adjacent to the rim of its western bluff. Because the power line right-of-way is kept free of large trees, an open, anthropogenic prairie-like grassland and shrub habitat has been maintained, possibly fitting the Hillside Prairie natural community type (Cohen et al. 2015), but with a significant presence of non-native species.

Paris Park (42° 51.348′N, 85° 35.075′W):

Paris Park (Figure 1, site 5) is an undeveloped park owned by Kent County, but with paths maintained by the City of Kentwood. Its wooded land along Plaster Creek is best classified as Floodplain Forest, with Mesic Southern Forest on the upland (Cohen et al. 2015). Emma Cole cites many plants in her *Flora* as having been collected from "Plaster Creek." However, it is uncertain how far "upstream" she collected along Plaster Creek, except for a fairly large number of specimens from the vicinity of Paris Town Hall, at Kalamazoo Ave. SE and 32nd Street SE (ca. 2 miles northwest of our Paris Park site).

Shadyside Park (42° 49.960′N, 85° 34.800′W):

Shadyside Park (Figure 1, site 6) is a property in the Kent County Parks system, located in Gaines Township, ca. 1.5 miles southeast of the village of Dutton, on the west side of Hammond Ave. Like Paris Park, this park also lies along Plaster Creek, and has a rich deciduous forest in an upland area, including a smaller portion of woods along Plaster Creek. Unlike Paris Park, however, most of the original floodplain area at Shadyside Park has been developed into open lawn for recreation, although a large floodplain restoration project was initiated at this site in the summer of 2018 and scheduled for completion by late summer, 2019 (Deanna Geelhoed, personal communication, June 17, 2019).

Bradford Dickinson White Nature Preserve (42°54.340′N, 85°21.545′W; 42°54.340′N, 85°21.646′W):

The Bradford Dickinson (B.D.) White Nature Preserve, falls just outside Cole's *Flora* "district" (see Figure 1, site 7) in Lowell Township, ca. 1.5 mi. SW of the City of Lowell between 36th Street and Alden Nash Avenue SE. Two distinct natural communities are present within the Preserve: Dry Southern Forest on the south- and west-facing slopes, and a broad Southern Shrub-Carr wetland along the bottomland creek (Cohen et al. 2015). Because these two habitats are so clearly demarcated, and per the request of the land owner (The Land Conservancy of West Michigan) we conducted and analyzed separate inventories for each habitat.

Sampling Methods

Botanical inventories were compiled over the course of fifteen weeks from May to October 2016; data from 2015 collections from five of the sites were also included. Each of the 8 habitats (Lamberton Creek and Soldiers Home Woods being combined) were visited on a bi-weekly basis to ensure a thorough inventory throughout the growing season. On each sampling day, the entirety of a site was meander-searched, keeping a keen eye out for any microhabitats within. As familiarity with the locations grew, areas of greater diversity were especially emphasized. During each visit, all species in flower or fruit were identified primarily using Voss and Reznicek (2012), Barnes and Wagner (2004), Crow and Hellquist (2000a, 2000b) and the Internet online sources MICHIGAN FLORA ONLINE (2011) and keys at Go Botany (Native Plant Trust 2019). Nomenclature follows that of MICHIGAN

FLORA ONLINE (2011), as this source includes both seed plants and pteridophytes, with updated recent taxonomic changes.

A total of 980 voucher specimens were collected to document the inventories of these eight sites. In some cases, forest trees were included in the inventories on the basis of sight identification without collecting voucher specimens. Plant species lists for each site were compiled, along with the relative abundance, habitat, location, and signs of disturbance. A complete set of voucher specimens has been deposited in the Calvin University Herbarium (CALVIN), and duplicates have been deposited in the herbaria of Michigan State University (MSC) and the University of Michigan (MICH). New county records and state listed species were specifically deposited at MICH, as well as numerous specimens of *Carex* confirmed or annotated by Dr. A. A. Reznicek.

Floristic Quality Assessments

Floristic Quality Index values were generated following the methodology described by Freyman et al. (2016) and calculated for each site utilizing the on-line Universal FQA Calculator (https://universalfqa.org) and the Michigan Floristic Quality Assessment Database–2014 (Reznicek et al. 2014). This assessment gives a quantitative estimate of a site's natural quality based on its existing floristic composition. The formula used to calculate a Floristic Quality Index (FQI) utilizes each species' coefficient of conservatism (or *C* value), along with species richness of native plants at the site to estimate habitat quality. The coefficient of conservatism (*C*) values range from 0 to 10, and values have been assigned to each species in Michigan based on the fidelity of that species to pristine conditions (Andreas et al. 2004; Miller and Wardrop 2006; Freyman et al. 2015). For instance, *C* values of 9 or 10 indicate a very strong affinity to a narrow range of undisturbed ecological conditions, whereas *C* values of 0–2 are generally associated with more widespread disturbance-tolerant species that can be found growing in a wide range of habitats. For individual sites a Mean *C* value ($\bar{C}$) was generated $\left(\bar{C} = \frac{\sum C}{n}\right)$. Multiplying $\bar{C}$ by the square root of the total number of plants (n) yields the Floristic Quality Index (FQI = $\bar{C} \times \sqrt{n}$). Additionally, by acknowledging the presence of non-native species and assigning a *C* value of 0 to each, a Total FQI can be generated, thereby reflecting (via comparison with the Native FQI) the impact of non-native species (e.g., disturbance) at a site.

The online Universal FQA Calculator also generates an Adjusted FQI score, which was first introduced in a study conducted within forested wetlands of central Pennsylvania (Miller and Wardrop 2006). One fundamental problem with the Total FQI calculation is the strong influence of species richness (often reflecting within-site habitat diversity). The Adjusted FQI corrects the index downwards for habitats with high native species richness but a low $\bar{C}$ value. The Adjusted FQI also shifts the index upwards for habitats that have a lower native species richness but a high $\bar{C}$ value. The Adjusted FQI formula is as follows:

$$\left(\frac{\bar{C}}{10} \times \frac{\sqrt{N}}{\sqrt{N+A}}\right)$$

where $\bar{C}$ is the mean *C* value for the site, N is the number of native species, and A is the number of non-native species.

Similarity Index

An index of similarity, the Simple Matching Index (Mueller-Dombois and Ellenberg 1974) was generated to evaluate the similarity of species composition between the historic list of species collected in the 1890s at Soldiers' Home Woods with our inventory taken in 2015–2016. In the same manner, the list of plants compiled from specimens collected at the Mill Creek Woods in 1895–1897 (mostly by Homer Skeels and Jennie Shaddick) and our inventory from 2015–2016 were compared. The Simple Matching Index is calculated as follows:

$$\text{Simple Matching Index} = 100 \quad (a+d) / (a+b+c+d)$$

where, a is the number of species present in both time periods, b is the number of species present in the 1890s, c is the number of species present in 2015–16, and d is the number of species from *both*

time periods that are *absent* from a potential species pool (Mueller-Dombois & Ellenberg 1974). Our potential species pool was generated from a compilation of the species inventories from several similar woodland locations throughout the Grand Rapids area that were inventoried for the project during 2015 and 2016. While some indices, such as the Sørensen's Index, measure the species held in common between two locations (or between two time frames), the Simple Matching Index considers the number of species *not* present within the floras being compared based on a larger potential species pool (Bradley and Crow 2010). A Simple Matching Index value above 50 indicates that the two communities being compared should be considered the same habitat type.

RESULTS AND DISCUSSION

Floristic Quality Assessments Overview

Most of Southwest Michigan's landscape has been significantly modified from its pre-European settlement character due to logging, agricultural development, and urban growth. Hence, our native biota has become restricted to relatively small, isolated tracts of natural landscapes, which have themselves been impacted by development. According to Herman et al. (2001), the principal elements of these native systems are poorly represented in the landscape today. Thus, to assist the evaluation of these natural landscapes, the Michigan Floristic Quality Assessment system was developed to aid in evaluating the significance of natural habitats with respect to Michigan's native biodiversity and natural landscapes. Table 1 reflects suggested thresholds in assessing significance of FQI numbers for Michigan (Herman et al. 2001).

Among the eight habitat sites inventoried in 2015 and 2016, the Total Floristic Quality Index (FQI) values ranged from a low of 22.0 (Black Hills) to highs of 47.4 (Paris Park) and 47.6 (Mill Creek Woods) (Table 2). The size of these parcels also varied quite widely, ranging from 3.2 ha (Black Hills) to over 40 ha (Paris Park). Interestingly, the locations used for historical comparisons had relatively high Total FQI values (Mill Creek = 47.6 and Soldiers' Home Woods = 38.9). Furthermore, Mill Creek's FQI was slightly higher than that of the unde-

TABLE 1. Significance of different ranges of Native FQI as calculated under the Michigan Floristic Quality Assessment System for evaluating individual natural habitats as reflecting Michigan's native biodiversity and natural landscapes, based on Herman et al. (2001).

Native FQI	Significance of habitat quality to Michigan	Value of site to Michigan
< 20	Minimal indication of natural quality; reflects much human disturbance.	Low value.
21–34	Average quality.	Moderate value.
35–50	Sufficient conservatism and richness in native flora; high quality.	Floristically important statewide.
> 50	Rare, highly specialized or extraordinarily high quality; significant component of Michigan's remaining native biodiversity.	Extremely high value; worthy of protection and conservation.

TABLE 2. Floristic Quality Assessment metrics for each site.

Site	Area (ha)	Total FQI	Native FQI	Adjusted FQI	Mean C	Total Species	Native Species	Non-Native Species
Mill Creek Woods	11.4	47.6	51.1	36.5	3.4	196	163 (83.2%)	33 (16.8%)
Soldiers' Home Woods	4.3	38.9	43.0	36.5	3.3	139	110 (79.1%)	29 (20.9%)
Mr. Lowes' Woods	5.4	36.3	40.2	36.5	3.3	120	100 (83.3%)	20 (16.7%)
Paris Park	40.8	47.2	50.0	39.2	3.7	163	149 (91.4%)	14 (8.6%)
Shadyside Park	8.7	27.6	31.2	35.1	3.1	79	64 (81.0%)	15 (19.0%)
Black Hills	3.2	22.0	27.9	27.9	2.2	102	62 (60.8%)	40 (39.2%)
B. D. White Preserve: Dry Southern Forest	24.9	37.6	40.4	38.7	3.6	109	97 (89.0%)	12 (11.0%)
B. D. White Preserve: Southern Shrub-Carr	3.9	43.5	45.3	39.6	3.8	131	122 (93.1%)	9 (6.9%)

veloped Paris Park (47.4), even though Mill Creek had a notably higher percentage of non-native species (16.8%) compared to Paris Park (8.6%). In this comparison, the Adjusted FQI value is perhaps a better indicator of site quality (Mill Creek = 36.5, Paris Park = 39.2), because it more directly considers the higher adventive composition of the local flora and corrects for high native species richness in conjunction with a lower $\bar{C}$. The higher Total FQIs of the other sites compared to their Native FQIs (in particular Shadyside Park) bear further witness to the influence of non-native species.

Individual Site Assessments

Mill Creek Woods

Table 2 shows the Floristic Quality Assessment metrics for Mill Creek Woods and Table 3 lists the species recorded. This site supports a high species richness with 196 species, 83% of which are native. The woods is no longer dominated by White Pine, nor does it have a "northern" character, as Emma Cole described it (Cole 1901). Having the highest species richness of any of our 2016 sites, today's species composition would more accurately be characterized as that of a Mesic Southern Forest community (Cohen et al. 2015), in which the dominant trees are Sugar Maple (*Acer saccharum*), Red Maple (*A. rubrum*), Beech (*Fagus grandifolia*), Red Oak (*Quercus rubra*), White Oak (*Q. alba*), Black Oak (*Q. velutina*) and Black Cherry (*Prunus serotina*). Black Maple (*A. nigrum*) and Box-elder (*A. negundo*) are found along the creek floodplain, as well as the occasional Hackberry (*Celtis occidentalis*) and Sycamore (*Platanus occidentalis*). The understory consists chiefly of Musclewood (*Carpinus caroliniana*), Witch-hazel (*Hamamelis virginiana*), and Alternate-leaved Dogwood (*Cornus alternifolia)*, with an abundance of Virginia creeper (*Parthenocissus quinquefolia*) and Poison-ivy (*Toxicodendron radicans*). In addition, we also encountered the "occasional Tulip-tree" (*Liriodendron tulipifera*), also noted by Cole (1901)—three so large that we believe they were growing in the woods at the time Homer Skeels and Jennie Shaddick were collecting in this woods (Figure 2).

Mill Creek Woods in the 1890s was documented with a sufficient number of

TABLE 3. List of species for Mill Creek comparing those documented in the 1890s vs. 2016.

Species	1890s	2016	Species	1890s	2016
Adiantum pedatum	x		*Diervilla lonicera*	x	
Ageratina altissima		x	*Dryopteris carthusiana*		x
Alliaria petiolata		x	*Dryopteris clintoniana*	x	
Allium canadense		x	*Dryopteris intermedia*		x
Allium vineale		x	*Dryopteris marginalis*		x
Anemone virginiana		x	*Elymus hystrix*		x
Anemone quinquefolia	x		*Elymus virginicus*		x
Antennaria parlinii		x	*Enemion biternatum*		x
Apocynum cannabinum		x	*Epigaea repens*	x	
Aralia nudicaulis		x	*Epilobium ciliatum*		x
Arctium lappa		x	*Epipactis helleborine*		x
Arctium minus		x	*Equisetum arvense*	x	x
Arisaema triphyllum	x	x	*Equisetum hyemale*		x
Asarum canadense		x	*Equisetum laevigatum*		x
Asclepias incarnata		x	*Equisetum scirpoides*	x	
Athyrium filix-femina	x	x	*Equisetum sylvaticum*	x	
Barbarea vulgaris		x	*Erigeron pulchellus*		x
Bartonia virginica	x		*Erythronium americanum*		x
Bromus nottowayanus		x	*Fallopia japonica*		x
Buglossoides arvensis	x		*Festuca subverticillata*		x
Caltha palustris		x	*Fragaria virginiana*		x
Cardamine bulbosa	x	x	*Galium aparine*		x
Cardamine diphylla		x	*Galium circaezans*		x
Cardamine douglassii	x		*Geranium maculatum*	x	x
Cardamine pensylvanica		x	*Geranium robertianum*		x
Carex bebbii		x	*Geum aleppicum*		x
Carex blanda		x	*Geum canadense*		x
Carex gracillima		x	*Glechoma hederacea*		x
Carex grisea		x	*Goodyera pubescens*	x	
Carex interior		x	*Helianthus decapetalus*		x
Carex leptonervia		x	*Helianthus divaricatus*		x
Carex pensylvanica		x	*Hemerocallis fulva*		x
Carex radiata		x	*Heracleum maximum*		x
Carex rosea		x	*Hesperis matronalis*		x
Carex sparganioides		x	*Hylodesmum glutinosum*		x
Caulophyllum thalictroides		x	*Hypopitys monotropa*	x	
Celastrus orbiculatus		x	*Impatiens capensis*		x
Chenopodium capitatum	x		*Impatiens pallida*		x
Chimaphila umbellata	x		*Laportea canadensis*		x
Circaea canadensis		x	*Lapsana communis*		x
Claytonia virginica		x	*Lechea mucronata*	x	
Clematis virginiana	x	x	*Lespedeza frutescens*	x	
Clintonia borealis	x		*Lespedeza hirta*	x	
Conopholis americana		x	*Lespedeza violacea*	x	
Coptis trifolia	x		*Lilium michiganense*	x	x
Corallorhiza maculata	x		*Liriodendron tulipifera*	x	x
Cryptotaenia canadensis		x	*Lonicera dioica*	x	
Cyperus esculentus	x		*Luzula acuminata*	x	
Cypripedium acaule	x		*Lysimachia ciliata*		x
Dactylis glomerata		x	*Maianthemum canadense*		x
Danthonia spicata		x	*Maianthemum racemosum*		x
Desmodium perplexum	x	x	*Maianthemum stellatum*	x	x
Desmodium rotundifolium	x		*Matteuccia struthiopteris*		x
Dichanthelium commutatum		x			

(*Continued next page*)

TABLE 3. List of species for Mill Creek comparing those documented in the 1890s vs. 2016 (*Continued*).

Species	1890s	2016	Species	1890s	2016
Medeola virginiana	x		*Ranunculus hispidus*		x
Menispermum canadense		x	*Ribes americanum*	x	
Mitchella repens		x	*Rudbeckia laciniata*	x	x
Monotropa uniflora	x	x	*Sanguinaria canadensis*		x
Muscari botryoides		x	*Sanicula odorata*		x
Oenothera biennis		x	*Saponaria officinalis*		x
Onoclea sensibilis		x	*Sceptridium oneidense*	x	
Orthilia secunda	x		*Smilax hispida*		x
Osmorhiza longistylis		x	*Solanum dulcamara*		x
Oxalis stricta		x	*Solidago altissima*		x
Parthenocissus quinquefolia		x	*Solidago caesia*		x
Persicaria virginiana		x	*Solidago flexicaulis*		x
Phleum pratense		x	*Sphenopholis intermedia*		x
Phlox divaricata		x	*Spiranthes cernua*	x	
Phlox paniculata		x	*Symphyotrichum lateriflorum*		x
Phryma leptostachya		x	*Symphyotrichum ontarionis*		x
Phytolacca americana		x	*Symphyotrichum urophyllum*		x
Pilea pumila		x	*Symplocarpus foetidus*		x
Platanthera aquilonis	x		*Taraxacum officinale*		x
Platanthera hookeri	x		*Thalictrum dasycarpum*		x
Platanthera orbiculata	x		*Thalictrum dioicum*		x
Poa sylvestris		x	*Toxicodendron radicans*		x
Podophyllum peltatum		x	*Trillium grandiflorum*		x
Polygonatum biflorum		x	*Urtica dioica*		x
Polygonatum pubescens		x	*Veronicastrum virginicum*		x
Polystichum acrostichoides	x	x	*Viola pubescens*	x	x
Prenanthes alba		x	*Viola rostrata*	x	x
Prenanthes altissima		x	*Viola sororia*		x
Prunella vulgaris		x	*Viola striata*		x
Pteridium aquilinum		x	*Vitis riparia*	x	x
Pyrola chlorantha	x		*Zizia aurea*		x
Ranunculus abortivus		x			

specimens to allow for a historical comparison. Table 3 provides a list, based on herbarium specimens, of species known to occur in the 1890s as compared with those recorded in 2015–2016. Floristic Quality Assessments were made of the two groups of species to give a sense of the historical habitat quality compared to that of today (Table 4). Since the collections made in the 1890s were intended to contribute to Cole's overall *Grand Rapids Flora* project rather than to be a full inventory of the Mill Creek woods, certain groups are notably absent. For instance, the historical specimens do not include trees, although Cole specifically mentions White Pine, Birch, Oaks, and the occasional Tulip Tree; likewise, the collecting of grasses and sedges (*Carex* spp.) was apparently avoided. Hence, our inventory generated far more species. Yet, some modified comparisons can still be meaningful. In Table 4 (second column) the FQA metrics are presented without trees (with the exception of Tulip Tree) and without graminoids, simulating Cole's select set of taxa from the 1890s (Table 4, first column).

Interestingly, when trees and graminoids are removed, the Total FQIs are quite

TABLE 4. Floristic Quality Assessment metrics for Mill Creek Woods based on (i) the 1895–1897 collections, (ii) the 2015–2016 collections excluding trees (other than *Liriodendron tulipifera*) and graminoids, and (iii) all of the 2015–2016 species encountered.

Metric	1895–1897 Collections	2015–2016 Trees and Graminoids Removed	2015–2016 All Species Encountered
Conservation-Based Metrics:			
Total FQI	40.0	38.6	47.6
Native FQI	40.3	40.0	51.1
Adjusted FQI	56.4	37.0	36.5
Total Mean *C*	5.6	3.4	3.4
Native Mean *C*	5.7	4.0	4.0
Species Richness:			
Total Species	51	117	196
Native Species	50 (98%)	100 (85.5%)	163 (83.2%)
Non-native Species	1 (2%)	17 (14.5%)	33 (16.8%)

similar for both lists—40.0 for 1890s and 36.8 for 2015–16 (Table 4, first and second columns). These calculations suggest that the woods both then and now represent high quality natural communities, possessing sufficient conservatism and richness to be important from a statewide perspective. Given that the species list (Table 3) for the 1890s is limited (51 species with only one non-native), the Adjusted FQI value, at 56.4, indicates the site was exceedingly important floristically and ecologically. However, with only one non-native species, the historic list could indicate a bias against collecting weeds. The 2015–16 Adjusted FQI value of 37.0 (trees and graminoids deleted) does reflect the impact of adventive species on overall floristic value. The current $\overline{C}$ value of 3.4, as contrasted with the historical $\overline{C}$ of 5.6, provides further evidence for the influence of disturbance over time, leading to the incursion of non-native species, which comprised 16.8% of the total flora in the 2015–2016 inventory.

The Simple Matching Index calculated for the Mill Creek site comparing the 1890s plant community with that of 2015–16 was 51.2%. This level of similarity suggests that the plant community at these two times is essentially the same vegetation type. This is somewhat surprising given Emma Cole's description of these woods as having a distinct "northern character," an impression that was not evident from our visits.

Overall, this site clearly was, and still is, an amazingly rich natural area. It stood out as a special area to Emma Cole, worthy of specific description in her *Flora*. And with a richness today of 196 species, 83.2% of which are native, Mill Creek Woods persists as a remarkable representation of southwestern Michigan's pre-European settlement forested habitat, existing today largely as an isolated remnant within the context of a highly urbanized landscape.

Soldiers' Home Woods

Table 2 shows the Floristic Quality Assessment metrics for Soldier's Home Woods and Table 5 lists the species recorded. This site supports a species richness of 139 species, 79.1% of which are native. The combined remnants at this

TABLE 5. List of species for Soldiers' Home Woods comparing the 1890s vs. 2015–16.

Species	1890s	2015–16	Species	1890s	2015–16
Actaea pachypoda	x		*Desmodium cuspidatum*	x	
Agrimonia pubescens	x		*Dioscorea villosa*		x
Alisma triviale		x	*Elymus villosus*	x	
Allium canadense		x	*Elymus virginicus*	x	x
Amphicarpaea bracteata	x		*Enemion biternatum*		x
Anemone canadensis	x	x	*Epilobium parviflorum*		x
Anemone quinquifolia	x		*Epipactis helleborine*		x
Arctium minus		x	*Equisetum arvense*		x
Arisaema dracontium		x	*Erythronium americanum*		x
Arisaema triphyllum		x	*Euonymus fortunei*		x
Asarum canadense		x	*Eutrochium purpureum*		x
Asclepias exaltata	x		*Festuca rubra*	x	
Asclepias purpurascens	x		*Galium obtusum*	x	
Barbarea vulgaris		x	*Geranium maculatum*		x
Boechera dentata	x	x	*Geum canadense*		x
Campanulastrum americanum	x		*Glyceria striata*		x
Cardamine concatenata		x	*Hackelia virginiana*		x
Cardamine douglassii	x		*Helenium autumnale*	x	
Cardamine pensylvanica		x	*Helianthus decapetalus*	x	
Carex blanda	x	x	*Hemerocallis fulva*		x
Carex bromoides	x	x	*Hesperis matronalis*		x
Carex careyana	x		*Hybanthus concolor*	x	
Carex davisii		x	*Hydrophyllum appendiculatum*		x
Carex flava	x		*Hypericum mutilum*	x	
Carex formosa	x		*Impatiens capensis*		x
Carex gracillima		x	*Iris pseudacorus*		x
Carex grayi	x	x	*Iris virginica*		x
Carex grisea	x		*Juncus dudleyi*		x
Carex hirtifolia	x		*Juncus pylaei*		x
Carex hitchcockiana	x		*Lactuca biennis*	x	
Carex interior		x	*Lapsana communis*		x
Carex laxiculmis	x		*Leersia virginica*		x
Carex laxiflora		x	*Liatris spicata*	x	
Carex lurida		x	*Lindera benzoin*	x	
Carex molesta		x	*Lysimachia ciliata*	x	x
Carex muskingumensis	x		*Lythrum salicaria*		x
Carex normalis		x	*Maianthemum racemosum*		x
Carex radiata		x	*Maianthemum stellatum*		x
Carex retrorsa	x		*Menispermum canadense*		x
Carex rosea	x	x	*Muhlenbergia sylvatica*	x	
Carex scabrata	x		*Myosotis laxa*		x
Carex scoparia	x		*Myosotis scorpioides*		x
Carex sparganioides	x	x	*Nasturtium microphyllum*		x
Carex vulpinoidea		x	*Onoclea sensibilis*		x
Carex woodii	x		*Oxalis dillenii*		x
Carpinus caroliniana	x		*Oxalis stricta*		x
Ceanothus americanus	x		*Oxypolis rigidior*	x	
Circaea canadensis		x	*Oryzopsis asperifolia*	x	
Conopholis americana		x	*Parthenocissus quinquefolia*		x
Convallaria majalis		x	*Persicaria pensylvanica*		x
Cryptotaenia canadense	x		*Persicaria virginiana*		x
Cyperus engelmannii	x		*Actaea pachypoda*		x
Cyperus esculentus		x	*Physalis heterophylla*	x	
Cyperus squarrosus	x				

(*Continued next page*)

TABLE 5. List of species for Soldiers' Home Woods comparing the 1890s vs. 2015–16 (*Continued*).

Species	1890s	2015–16	Species	1890s	2015–16
Phytolacca americana		x	*Sonchus oleraceus*	x	
Piptatherum racemosum	x		*Stellaria longifolia*	x	
Poa alsodes	x		*Symphyotrichum lanceolatum*		x
Podophyllum peltatum		x	*Symphyotrichum lateriflorum*		x
Polygonatum biflorum		x	*Symphyotrichum ontarionis*		x
Polymnia canadensis	x		*Symplocarpus foetidus*		x
Prunella vulgaris		x	*Teucrium canadense*		x
Ranunculus abortivus		x	*Thalictrum dasycarpum*	x	x
Ranunculus hispidus	x		*Thalictrum dioicum*		x
Rumex altissimus		x	*Thalictrum pubescens*		x
Sagittaria latifolia	x		*Torreyochloa pallida*		x
Sanguinaria canadensis	x	x	*Toxicodendron radicans*		x
Schizachne purpurascens	x		*Trifolium campestre*		x
Schoenoplectus pungens		x	*Trillium grandiflorum*		x
Scirpus atrovirens		x	*Verbascum thapsus*		x
Scirpus cyperinus		x	*Verbena hastata*		x
Scrophularia marilandica		x	*Verbena urticifolia*		x
Scutellaria lateriflora		x	*Vernonia missurica*	x	
Silene latifolia		x	*Vitis riparia*		x
Smilax ecirrata		x	*Viola canadensis*	x	
Solanum dulcamara		x	*Viola sororia*	x	
Solidago gigantea		x			

site can be classified as Mesic Southern Forest, with a portion along Lamberton Creek classified as Floodplain Forest (Cohen et al. 2015). Sugar Maple (*Acer saccharum*), Beech (*Fagus grandifolia*), and Red Oak (*Quercus rubra*) are the predominant trees, and Black Cherry (*Prunus serotina*), Choke Cherry (*P. virginiana*), Red Oak (*Quercus rubra*), White Oak (*Q. alba*), and Basswood (*Tilia americana*) are also present; Black Ash (*Fraxinus nigra*) and Hackberry (*Celtis occidentialis*) occur in wetter spots, along with Black Maple (*Acer nigrum*), especially along the creek. The spring flora is well established and is highlighted by Wild Ginger (*Asarum canadense*), Cut-leaved Toothwort (*Cardamine concatenata*), Pennsylvania Bitter Cress (*C. pensylvanica*), Wild Geranium (*Geranium maculatum*), Great Waterleaf (*Hydrophyllum appendiculatum*), False Spikenard (*Maianthemum racemosum*), Starry False Solomon-seal (*M. stellatum*), Wild Blue Phlox (*Phlox divaricata*), and Bloodroot (*Sanguinaria canadense*). Perhaps noteworthy is the presence of a small population of White Trout Lily (*Erythronium albidum*) growing in the woods along Lamberton Creek adjacent to a much larger population of Yellow Trout Lily (*E. americanum*).

A portion of the woods on the south side of the Veterans' facility is wet and springy. Both woodland and wetland species of *Carex* are well represented, such as *Carex blanda*, *C. brevior*, *C. bromoides*, *C. gracillima*, *C. grayi*, *C. interior*, *C. laxiflora*, *C. radiata*, *C. rosea*, *C. sparganioides*, and *C. vulpinoidea*.

As was the case with Mill Creek Woods, Emma Cole and several other collectors amassed a sufficient number of herbarium specimens in the 1890s to allow for a general historical comparison. Table 5 provides a list of species collected in Soldiers' Home Woods in the 1890s compared with those recorded in 2015–2016.

TABLE 6. Floristic Quality Assessment metrics for Soldiers' Home Woods based on (i) the 1890s collections and (ii) the 2015–2016 collections excluding graminoids, and (iii) all of the 2015–2016 species encountered.

Metric	1895–1897 Collections	2015–2016 Graminoids Removed	2015–2016 All Species Encountered
Conservation-Based Metrics:			
Total FQI	41.7	32.0	38.9
Native FQI	41.8	34.4	43.0
Adjusted FQI	53.1	34.4	36.5
Total Mean *C*	5.3	3.2	3.3
Native Mean *C*	5.4	3.8	4.1
Species Richness:			
Total Species	62	100	139
Native Species	60 (96.8%)	82 (82%)	110 (79.1%)
Non-native Species	2 (3.2%)	18 (18%)	29 (20.9%)

However, because we noticed that the list generated from herbarium specimens collected in the 1890s did not include tree or graminoid species, we again excluded these groups from the 2015–2016 list for a more meaningful assessment. Table 6 presents a comparison of Floristic Quality Assessment metrics, historical vs. today. It shows that the woods in Cole's day (Table 6, first column) scored a Total FQI of 41.7 (based on 62 species) and a Total $\overline{C}$ value of 5.3. The 2015–2016 Total FQI (excluding trees and graminoids) (Table 6, second column) was lower at 32.0 (based on 100 species), and the Total $\overline{C}$ value of 3.2 was also lower, thereby underscoring the impact of disturbance and the corresponding incursion of non-native species since Cole's time. Interestingly, the Adjusted FQI boosts the value of the historic woods from 41.7 to a remarkable 53.1, whereas the modern Adjusted FQI increased only slightly from 32.0 to 34.4, which further illustrates the strong impact of disturbance on the Soldiers' Home Woods over time.

As an indication of similarity between the historical site of the 1890s versus today, the Simple Matching Index (Mueller-Dombois and Ellenberg 1974) calculated for the Soldiers' Home Woods is 55.3%, strongly suggesting that the two inventories separated by over 100 years do indicate the same vegetation type. In other words, although the overall character of the habitat has not changed over time, the changes we report can be ascribed to the loss of native species and the addition of non-native species within the same Mesic Southern Forest community type.

Table 6 (third column) presents the FQA metrics for all species present, showing that when the tree species are included, both the Native FQI (43.0) and the Total FQI (38.9) rise. Even with the presence of non-native species today, particularly given its largely urban context, this is still a rich site that is significant from a statewide perspective.

Mr. Lowes' Woods

Table 2 shows the Floristic Quality Assessment metrics for Mr. Lowes' Woods and Table 7 lists the species recorded. This site supports a species richness of 120

TABLE 7. Species present at Mr. Lowes' Woods. Total species richness: 120 species.

Acer negundo	*Catalpa speciosa*	*Poa pratensis*
Acer nigrum	*Celastrus orbiculatus*	*Poa trivialis*
Acer platanoides	*Circaea canadensis*	*Podophyllum peltatum*
Acer rubrum	*Cornus foemina*	*Polygonatum pubescens*
Acer saccharinum	*Crataegus coccinea*	*Polystichum acrostichoides*
Acer saccharum	*Dactylis glomerata*	*Populus tremuloides*
Actaea pachypoda	*Dryopteris carthusiana*	*Potentilla indica*
Alliaria petiolata	*Elaeagnus umbellata*	*Potentilla simplex*
Amelanchier laevis	*Elymus hystrix*	*Prenanthes alba*
Asclepias incarnata	*Elymus riparius*	*Prunus serotina*
Asplenium platyneuron	*Enemion biternatum*	*Prunus virginiana*
Athyrium filix-femina	*Erythronium americanum*	*Quercus bicolor*
Barbarea vulgaris	*Fagus grandifolia*	*Quercus rubra*
Berberis thunbergii	*Floerkea proserpinacoides*	*Ranunculus hispidus*
Cardamine pensylvanica	*Frangula alnus*	*Ranunculus recurvatus*
Carex albursina	*Fraxinus americana*	*Rhamnus alnifolia*
Carex amphibola	*Galium aparine*	*Rosa multiflora*
Carex blanda	*Geranium maculatum*	*Rubus allegheniensis*
Carex cephalophora	*Geranium robertianum*	*Rubus hispidus*
Carex communis	*Geum canadense*	*Rubus occidentalis*
Carex cristatella	*Glyceria striata*	*Rubus strigosus*
Carex gracillima	*Hackelia virginiana*	*Rumex obtusifolius*
Carex granularis	*Hamamelis virginiana*	*Sanguinaria canadensis*
Carex grayi	*Hesperis matronalis*	*Scirpus expansus*
Carex grisea	*Impatiens capensis*	*Scirpus hattorianus*
Carex hystericina	*Juncus tenuis*	*Scrophularia marlindica*
Carex jamesii	*Lindera benzoin*	*Solidago caesia*
Carex lupulina	*Lithospermum latifolium SC*	*Solidago flexicaulis*
Carex molesta	*Lonicera bella*	*Sphenopholis intermedia*
Carex ormostachya	*Lonicera morrowii*	*Thalictrum dioicum*
Carex pensylvanica	*Lonicera tatarica*	*Tilia americana*
Carex prasina	*Maianthemum racemosum*	*Toxicodendron radicans*
Carex radiata	*Matteuccia struthiopteris*	*Trillium grandiflorum*
Carex rosea	*Osmunda claytoniana*	*Triosteum aurantiacum*
Carex sparganioides	*Ostrya virginiana*	*Ulmus americana*
Carex stipata	*Parthenocissus quinquefolia*	*Veronica serpyllifolia*
Carex swanii	*Persicaria maculosa*	*Viburnum acerifolium*
Carex vulpinoidea	*Persicaria virginiana*	*Viola pubescens*
Carya cordiformis	*Phalaris arundinacea*	*Viola sororia*
Carya ovata	*Poa palustris*	*Vitis riparia*

species, 83.3% of which are native. The Floristic Quality Assessment generated a Total $\bar{C}$ 3.3 and a Native FQI of 40.2 (Table 2). Most of the woods at this just-being-developed Grand Rapids city park, especially on the land surrounding the ravines, consists of secondary growth, woody plants having invaded agricultural lands, and is therefore of relatively low-quality value. The vegetation found in the ravines, however, is high quality and can be classified as Mesic Southern Forest (Cohen et al. 2015) and includes a number of very large trees (greater than 1m dbh) of Sugar Maple (*Acer saccharum*), Red Maple (*Acer rubrum*), Shagbark Hickory (*Carya ovata*), Wild Black Cherry (*Prunus serotina*), Red Oak (*Quercus rubra*) and Basswood (*Tilia americana*), with an understory of Witch-hazel

(*Hamamelis virginiana*), Hop hornbeam (*Ostrya virginiana*) and young hardwood saplings.

The clay soils of the forest floor support a diverse spring flora. Sedge diversity is particularly high with *Carex jamesii* among the most abundant sedges, along with a relatively even mix of *Carex albursina*, *Carex blanda*, *C. cephalophora*, *C. communis, C. gracillima*, *C. molesta*, *C. ormostachya*, *C. pensylvanica*, *C. radiata*, *C. rosea*, *C. sparganioides*, and *C. swanii*. Lower areas at the bottom of ravines support *Carex prasina*, *C. stipata*, and *C. vulpinoidea*. Spring wildflowers are represented by White Baneberry (*Actaea pachypoda*), Common Trillium (*Trillium grandiflorum*), May-Apple (*Podophyllum peltatum*), Yellow Trout Lily (*Erythronium americanum*), False Rue-anemone (*Enemion biternatum*), False Mermaid (*Floerkea proserpinacoides*), Bloodroot (*Sanguinaria canadensis*), and Wild Geranium (*Geranium maculatum*). Unfortunately, this relatively richer area represents a small proportion of the overall woods. Although the woods retains many large trees, a number of the more mature trees were harvested in the spring of 2015, and considerable slash was left, causing significant disturbance to this ravine area. Thankfully, as of spring 2019 the church that owns part of the woods has cleaned up much of the slash recently and the ravine woods remains a very nice, high quality site.

The southwest portion of the city-owned property is an old, shallow farm pond, presumably part of the Lowes farm, and is choked with the submersed White Water Crowfoot (*Ranunculus longirostris*) and a submersed pondweed (*Potamogeton berchtoldii*). A number of aquatic and wetland species occur on the margin, including: Southern Water-plantain (*Alisma subcordatum*), Sedges (*Carex comosa*, *C. grayi*, *C. hystericina*, *C. vulpinoidea*), Fowl Manna Grass (*Glyceria striata*), Mild Water-pepper (*Persicaria hydropiperoides*), Bulrush (*Scirpus atrovirens*) and Greater Duckweed (*Spirodela polyrhiza*). Since this pond is such a different habitat than the adjacent forest, we did not include its flora in our Floristic Quality Assessment of Mr. Lowe's Woods.

The woods on the east side of the powerline right-of-way is second growth, with numerous adventive species and reduced floristic value compared to the ravines. Furthermore, a 1938 aerial photograph (Figure 3) shows that the original Mr. Lowes' Woods was restricted to the deep ravines while the surrounding plateau was open agricultural land, as was likely the case in 1893. By contrast, the recent Google Earth image with the original Mr. Lowes' Woods boundary superimposed, shows the surrounding plateau now covered with secondary woods. Thus, this secondary wooded land (owned by the City) was also excluded from the floristic inventory and assessment.

An interesting historical note which initially drew the locality to our attention, is that on June 2, 1892, Elsie Lowes (MSC) collected a plant in the woods occupying deep ravines on the Lowes family farm that turned out to be Green Violet *(Hybanthus concolor*), a state-listed "Special Concern" species today (Michigan Natural Features Inventory 2016). A specimen of *H. concolor* was collected at Lowes' Woods the following year by Emma Cole on June 10, 1893 (MICH), which suggests that Elsie had taken Miss Cole to see this rare plant. Another plant of historical significance was collected by Elsie Lowes at this site the same year as the Green Violet—Goldseal (*Hydrastis canadensis*) (Crow 2017). Oddly,

there is no specimen collected by Cole on her visit to the woods the following year. Having scoured the area thoroughly, neither of these rare plants appear to have persisted. However, in 2019 we did document a new "Special Concern" species for Mr. Lowes' Woods, American Gromwell (*Lithospermum latifolium*), consisting of around 10 clumps of robust plants and a few other scattered individuals.

Mr. Lowes' Woods appears to continue to be a case-in-point representing what Cole (1901) wrote in her Introduction: "Since the district has become more thickly settled, it is undergoing rapid transformation. Much of the swampland is being drained, cleared, and utilized; forests are being deprived of their valuable timber, and uplands converted into farms. The woodlands at present consist mostly of the 'wood-lot' reserved by the farmer."

Paris Park

Table 2 shows the Floristic Quality Assessment metrics for Paris Park and Table 8 lists the species recorded. This site supports a high species richness of 163 species, 91.4% of which are native. The Total FQI of 47.2 and the Adjusted FQI of 39.2 both indicate that this site is significant from a statewide perspective. The Total $\bar{C}$ value of 3.7 is also strong. These are rich deciduous forests: the Floodplain Forest adjacent to Plaster Creek is dominated by Sugar Maple (*Acer saccharum*), Silver Maple (*Acer saccharinum*), Red Maple (*Acer rubrum*), Box-elder (*Acer negundo*), and White Ash (*Fraxinus americana*), along with Black Cherry (*Prunus serotina*), Cottonwood (*Populus deltoides*), American Elm (*Ulmus americana*), Sycamore (*Platanus occidentalis*), and willow (*Salix* spp.). Poison-ivy (*Toxicodendron radicans*) abounds in the floodplain, and Green Dragon (*Arisaema dracontium*) is remarkably frequent.

The Mesic Southern Forest adjacent to the Floodplain Forest is dominated by Sugar Maple (*Acer saccharum*), Beech (*Fagus grandifolia*), Basswood (*Tilia americana*), with understory Musclewood (*Carpinus caroliniana*), Witch-hazel (*Hamamelis virginiana*), Alternate-leaved Dogwood (*Cornus alternifolia*), Moonseed (*Menispermum canadense*) and an abundance of Virginia Creeper (*Parthenocissus quinquefolia*). This is, indeed, a prime site ecologically and floristically. Thankfully, it is preserved as part of the Kent County park system as an undeveloped park, with minimal impact of paved and unpaved trails for recreational hiking and biking.

Shadyside Park

Table 2 shows the Floristic Quality Assessment metrics for Shadyside Park and Table 9 lists the species recorded. This site supports a species richness of 79 species, 81.0% of which are native. Although the park is situated along Plaster Creek, the highest quality habitat is located on higher ground north of the creek, exhibiting more of an upland flora, best classified as Mesic Southern Forest. A much smaller and more disturbed section of woods along Plaster Creek more closely resembles Floodplain Forest (Cohen et al. 2015). The upland forest is characterized by Sugar Maple (*Acer saccharum*), Beech (*Fagus grandifolia*), Black Cherry (*Prunus serotina*), American Elm (*Ulmus americana*), and an

TABLE 8. Species present at Paris Park. Total species richness: 163 species.

Acer negundo
Acer saccharinum
Acer saccharum
Agrimonia gryposepala
Alisma triviale
Alliaria petiolata
Allium canadense
Allium vineale
Amphicarpaea bracteata
Anemone canadensis
Apocynum cannabinum
Arabidopsis thaliana
Arisaema dracontium
Arisaema triphyllum
Asclepias incarnata
Barbarea vulgaris
Boehmeria cylindrica
Caltha palustris
Calystegia sepium
Cardamine bulbosa
Carex amphibola
Carex bebbii
Carex blanda
Carex bromoides
Carex cephaloidea
Carex crinita
Carex echinodes
Carex gracilescens
Carex grayi
Carex grisea
Carex hirtifolia
Carex laxiculmis
Carex laxiflora
Carex lupulina
Carex retrorsa
Carex rosea
Carex sparganioides
Carex stipata
Carex vulpinoidea
Carpinus caroliniana
Carya ovata
Cephalanthus occidentalis
Cerastium fontanum
Chelone glabra
Cicuta maculata
Cinna arundinacea
Circaea canadensis
Claytonia virginica
Cornus alternifolia
Cryptotaenia canadensis
Dichanthelium latifolium
Dryopteris carthusiana
Elymus hystrix
Elymus virginicus
Enemion biternatum
Equisetum arvense
Erigeron annuus
Erythronium americanum
Eutrochium maculatum
Fagus grandifolia
Festuca subverticillata
Floerkea proserpinacoides
Fragaria virginiana
Fraxinus americana
Fraxinus pennsylvanica
Galium aparine
Galium circaezans
Galium obtusum
Geranium maculatum
Geum aleppicum
Geum canadense
Geum vernum
Glyceria striata
Hamamelis virginiana
Hesperis matronalis
Hieracium aurantiacum
Hydrophyllum canadense
Hydrophyllum virginianum
Hypopitys monotropa
Impatiens capensis
Iris pseudacorus
Iris virginica
Juglans nigra
Juncus tenuis
Laportea canadensis
Lemna minor
Lilium michiganense
Lindera benzoin
Lobelia cardinalis
Lobelia siphilitica
Lysimachia ciliata
Lysimachia nummularia
Lythrum salicaria
Medicago lupulina
Menispermum canadense
Monotropa uniflora
Onoclea sensibilis
Osmorhiza claytonii
Ostrya virginiana
Oxalis dillenii
Parthenocissus quinquefolia
Penstemon digitalis
Persicaria virginiana
Phryma leptostachya
Pilea pumila
Plantago rugelii
Platanus occidentalis
Podophyllum peltatum
Populus deltoides
Prunus serotina
Prunus virginiana
Quercus alba
Quercus bicolor
Quercus macrocarpa
Quercus muehlenbergii
Quercus rubra
Quercus velutina
Ranunculus abortivus
Ranunculus hispidus
Rhus glabra
Ribes americanum
Ribes cynosbati
Rosa multiflora
Rubus allegheniensis
Rubus occidentalis
Rudbeckia hirta
Rudbeckia laciniata
Rudbeckia triloba
Rumex obtusifolius
Rumex verticillatus
Sagittaria latifolia
Salix alba
Salix eriocephala
Samolus parviflorus
Sanguinaria canadensis
Sanicula odorata
Scirpus atrovirens
Scutellaria lateriflora
Sisyrinchium angustifolium
Smilax hispida
Solidago canadensis
Solidago gigantea
Sphenopholis intermedia
Symphyotrichum novae-angliae
Symphyotrichum ontarionis
Symplocarpus foetidus
Teucrium canadense
Thalictrum dasycarpum
Thalictrum dioicum
Thalictrum thalictroides
Tilia americana
Toxicodendron radicans
Trillium grandiflorum
Ulmus americana
Urtica dioica
Verbena urticifolia
Viburnum acerifolium
Viburnum trilobum
Viola canadensis
Viola pubescens
Viola sororia
Viola striata
Vitis riparia

TABLE 9. Species present at Shadyside Park. Total species richness: 79 species.

Acer saccharum	*Elymus virginicus*	*Phlox divaricata*
Ailanthus altissima	*Enemion biternatum*	*Phytolacca americana*
Alliaria petiolata	*Epifagus virginiana*	*Poa pratensis*
Allium tricoccum	*Equisetum arvense*	*Podophyllum peltatum*
Anemone canadensis	*Erythronium americanum*	*Polygonatum biflorum*
Arisaema triphyllum	*Euonymus obovatus*	*Potentilla norvegica*
Asimina triloba	*Fagus grandifolia*	*Prunus serotina*
Barbarea vulgaris	*Galium aparine*	*Rumex obtusifolius*
Cardamine concatenata	*Geranium robertianum*	*Salix eriocephala*
Carex albursina	*Geum aleppicum*	*Sambucus canadensis*
Carex cristatella	*Geum canadense*	*Sambucus racemosa*
Carex gracilescens	*Geum vernum*	*Silene latifolia*
Carex gracillima	*Hydrophyllum virginianum*	*Solanum carolinense*
Carex grayi	*Hypericum punctatum*	*Symplocarpus foetidus*
Carex hirtifolia	*Impatiens capensis*	*Taraxacum officinale*
Carex intumescens	*Juncus tenuis*	*Teucrium canadense*
Carex jamesii	*Laportea canadensis*	*Torilis japonica*
Carex laxiflora	*Leonurus cardiaca*	*Toxicodendron radicans*
Carex leptonervia	*Lonicera ×bella*	*Trifolium pratense*
Carex pensylvanica	*Lysimachia ciliata*	*Trillium grandiflorum*
Carex rosea	*Maianthemum racemosum*	*Ulmus americana*
Carex sparganioides	*Morus alba*	*Verbascum thapsus*
Carex tribuloides	*Osmorhiza longistylis*	*Viola canadensis*
Cichorium intybus	*Oxalis stricta*	*Viola pubescens*
Circaea canadensis	*Parthenocissus quinquefolia*	*Viola sororia*
Claytonia virginica	*Persicaria pensylvanica*	
Dicentra cucullaria	*Persicaria virginiana*	

abundance of Poison-ivy (*Toxicodendron radicans*), both climbing and sprawling growth forms. Among its spring flora are Wild Leek (*Allium tricoccum*), Canada Violet (*Viola canadensis*), Yellow Violet (*V. pubescens*), Smooth Sweet-cicely (*Osmorhiza longistylis*), False Rue-anemone (*Enemion biternatum*), Common Trillium (*Trillium grandiflorum*), Virginia Waterleaf (*Hydrophyllum virginianum*), Yellow Trout Lily (*Erythronium americanum*), and Spring Beauty (*Claytonia virginica*). Perhaps even more interesting is the richness of the woodland sedge flora, including *Carex albursina*, *C. blanda*, *C. cristatella*, *C. gracillima*, *C. grayi*, *C. grisea*, *C. hirtifolia*, *C. intumesens*, *C. jamesii*, *C. lupulina*, *C. pensylvanica*, *C. rosea*, *C. sparganioides*, *C. tribuloides*, and *C. woodii*.

Because of its relatively low overall species richness, the 27.6 Total FQI for Shadyside Park increases to an Adjusted FQI of 35.1, just above the threshold of marginal statewide significance. The relatively high percentage of non-native species (19%) indicates a history of disturbance; yet this small parcel retains an important component of native flora and is therefore worthy of continued protection and conservation.

Black Hills

Table 2 shows the Floristic Quality Assessment metrics for the Black Hills and Table 10 lists the species recorded. This site supports a species richness of

TABLE 10. Species present at Black Hills. Total species richness: 102 species.

Acer platanoides	*Erodium cicutarium*	*Polygonatum biflorum*
Acer saccharum	*Euphorbia corollata*	*Populus grandidentata*
Achillea millefolium	*Fagus grandifolia*	*Prunella vulgaris*
Alliaria petiolata	*Fragaria virginiana*	*Prunus serotina*
Allium vineale	*Fraxinus americana*	*Prunus virginiana*
Andropogon gerardii	*Galium aparine*	*Quercus alba*
Anemone virginiana	*Galium asprellum*	*Quercus rubra*
Apocynum androsaemifolium	*Galium circaezans*	*Quercus velutina*
Asparagus officinalis	*Geranium maculatum*	*Rhamnus cathartica*
Barbarea vulgaris	*Helianthus hirsutus*	*Rhus glabra*
Berteroa incana	*Hypericum perforatum*	*Rhus typhina*
Cardamine pensylvanica	*Juniperus virginiana*	*Robinia pseudoacacia*
Carex grisea	*Lathyrus latifolius*	*Rudbeckia hirta*
Carex leptonervia	*Lathyrus odoratus*	*Rumex acetosella*
Carex muehlenbergii	*Lechea mucronata*	*Rumex altissimus*
Centaurea diffusa	*Leonurus cardiaca*	*Sassafras albidum*
Centaurea stoebe	*Lepidium campestre*	*Setaria viridis*
Cichorium intybus	*Lespedeza hirta*	*Silene latifolia*
Circaea canadensis	*Leucanthemum vulgare*	*Solanum carolinense*
Convallaria majalis	*Linaria vulgaris*	*Solanum dulcamara*
Convolvulus arvensis	*Lonicera japonica*	*Solidago canadensis*
Crataegus coccinea	*Luzula multiflora*	*Solidago juncea*
Crataegus mollis	*Lysimachia lanceolata*	*Solidago speciosa*
Crataegus punctata	*Maianthemum racemosum*	*Teucrium canadense*
Dactylis glomerata	*Melilotus albus*	*Tradescantia ohiensis*
Daucus carota	*Melilotus officinalis*	*Tragopogon dubius*
Desmodium canadense	*Monarda fistulosa*	*Tragopogon pratensis*
Desmodium paniculatum	*Morus alba*	*Verbascum blattaria*
Dianthus armeria	*Nepeta cataria*	*Verbascum thapsus*
Echinochloa crusgalli	*Oxalis dillenii*	*Verbena urticifolia*
Elaeagnus umbellata	*Parthenocissus quinquefolia*	*Vernonia missurica*
Equisetum arvense	*Phlox divaricata*	*Veronicastrum virginicum*
Eragrostis spectabilis	*Phytolacca americana*	*Viburnum acerifolium*
Erigeron annuus	*Podophyllum peltatum*	*Vitis riparia*

102 species, 60.8% of which are native. Among all the inventories, this site has the lowest Total FQI value (22.0) (see Table 2).

The Black Oak trees that the Black Hills got its name from are still present, occupying a small grove at the eastern edge of the plateau, but the site is dominated by an open grass and shrub landscape, due to the impact of the major power line right-of-way that is managed to keep the site open. It is a highly disturbed site with many adventive species (40), yet the base of the south-facing slope is curiously dominated by native prairie plants even though the site is surrounded by industrial and residential land use with no indigenous prairie nearby. Among the species occupying this apparent prairie or savannah remnant are Big Bluestem (*Andropogon gerardii)*, Switch Grass (*Panicum virgatum*), Indian Grass (*Sorghastrum nutans*), goldenrods (*Solidago canadensis*, *S. juncea*, *S. speciosa*), Showy Tick-trefoil (*Desmodium canadense*), Culver's-root (*Veronicastrum virginicum*), Whorled Loosestrife (*Lysimachia quadrifolia*), Wild Bergamot (*Monarda fistulosa*), Wood-sage (*Teucrium canadense*), Hairy Bush-clover (*Les-*

pedeza hirta), Smooth Sumac (*Rhus glabra*), and Staghorn Sumac (*Rhus typhina*). Of special interest was the discovery of a few plants of Hairy Sunflower (*Helianthus hirsutus*), a rare species with Special Concern status for Michigan, and also a new county record for Kent County. A seldom documented non-native sedge, *Carex aggregata*, also represented a new county record. With so many prairie plants present on the steep south-facing slope, one wonders if this community has actually persisted from the days of Chief Blackbird and the Ottawa people who were known for using fire as a management tool.

B. D. White Preserve: Dry Southern Forest

Table 2 shows the Floristic Quality Assessment metrics for B. D. White Preserve: Dry Southern Forest and Table 11 lists the species recorded. This site sup-

TABLE 11. Species present at B. D. White Preserve—Southern Dry Forest. Total species richness: 109 species.

Acer rubrum	*Erigeron philadelphicus*	*Poa alsodes*
Acer saccharum	*Euonymus alatus*	*Poa compressa*
Achillea millefolium	*Eutrochium maculatum*	*Podophyllum peltatum*
Agrimonia gryposepala	*Festuca saximontana*	*Populus grandidentata*
Allium canadense	*Festuca subverticillata*	*Potentilla simplex*
Amelanchier spicata	*Fragaria virginiana*	*Prunella vulgaris*
Antennaria parlinii	*Galium circaezans*	*Prunus serotina*
Anthoxanthum odoratum	*Gaultheria procumbens*	*Pteridium aquilinum*
Aralia nudicaulis	*Gaylussacia baccata*	*Pyrola americana*
Arisaema triphyllum	*Geum canadense*	*Pyrola elliptica*
Asplenium platyneuron	*Hackelia virginiana*	*Quercus rubra*
Carex blanda	*Hamamelis virginiana*	*Quercus velutina*
Carex bromoides	*Hepatica americana*	*Ranunculus abortivus*
Carex cephalophora	*Hieracium caespitosum*	*Ribes cynosbati*
Carex cristatella	*Hieracium gronovii*	*Rosa carolina*
Carex gracillima	*Hieracium venosum*	*Rosa multiflora*
Carex interior	*Iris virginica*	*Rubus allegheniensis*
Carex molesta	*Juncus pylaei*	*Rubus setosus*
Carex pensylvanica	*Juncus tenuis*	*Rudbeckia fulgida*
Carex rosea	*Juniperus virginiana*	*Rumex acetosella*
Carex stipata	*Laportea canadensis*	*Sanicula odorata*
Carex swanii	*Luzula multiflora*	*Solidago caesia*
Carex vulpinoidea	*Lysimachia lanceolata*	*Solidago patula*
Carpinus caroliniana	*Maianthemum canadense*	*Solidago rugosa*
Cerastium fontanum	*Maianthemum racemosum*	*Symphyotrichum cordifolium*
Chimaphila maculata	*Malus pumila*	*Symphyotrichum lateriflorum*
Chimaphila umbellata	*Monotropa uniflora*	*Symphyotrichum ontarionis*
Circaea canadensis	*Muhlenbergia frondosa*	*Vaccinium angustifoliium*
Cornus florida	*Osmorhiza claytonii*	*Vaccinium myrtilloides*
Corylus americana	*Packera aurea*	*Verbascum thapsus*
Dichanthelium latifolium	*Parthenocissus quinquefolia*	*Veronica officinalis*
Dryopteris carthusiana	*Penstemon hirsutus*	*Viburnum acerifolium*
Elaeagnus umbellata	*Phryma leptostachya*	*Viola labradorica*
Elymus riparius	*Physocarpus opulifolius*	*Viola macloskeyi*
Elymus villosus	*Picea glauca*	*Zizia aurea*
Epipactis helleborine	*Pinus resinosa*	
Equisetum laevigatum	*Pinus strobus*	

ports a species richness of 109 species, 89.0% of which are native. This excellent example of Dry Southern Forest yielded a Mean $\bar{C}$ of 3.6 and a Total FQI of 37.6.

The forest is characterized by Red Oak (*Quercus rubra*), White Oak (*Q. alba),* Black Oak (*Q. velutina*), Sugar Maple (*Acer saccharum*), and Red Maple (*A. rubrum*), with a sparse understory of scattered shrubs and subshrubs, including Musclewood (*Carpinus caroliniana*), Flowering Dogwood (*Cornus florida*), Canada Blueberry (*Vaccinium myrtilloides*) and Low Sweet Blueberry (*V. angustifolium*). A number of woodland sedges are also present, including *Carex pensylvanica* (perhaps the most common, forming a sedge "lawn" in many parts of the woods), *C. blanda*, *C. cephalophora*, *C. gracillima*, *C. rosea*, and *C. swanii*. A portion of the upland woods also included a Red Pine (*Pinus resinosa*) plantation with a decidedly disturbed aspect, in contrast to the rest of the Dry Southern Forest.

B. D. White Preserve: Southern Shrub-Carr Wetland

Table 2 shows the Floristic Quality Assessment metrics for B. D. White Preserve: Southern Shrub-Carr and Table 12 lists the species recorded. This site supports a species richness of 131 species, 93.1% of which are native. This large open, shrub-dominated wetland community is of very high natural quality, as evidenced by a Total FQA of 43.5, and a Mean $\bar{C}$ value of 3.8 (highest of all our sites, see Table 2).

This Southern Shrub-Carr Wetland is characterized by widely scattered shrubs and small trees, with an abundance of graminoids occupying a wide swath of saturated organic substrate adjacent to a small meandering creek. Predominant shrubs include several willows (*Salix eriocephala*, *S. bebbiana*, *S. exigua*, *S. lucida*, *S. myricoides*, *S. petiolaris*, *S. sericea*, and *S. serissima*), Poison Sumac (*Toxicodendron vernix*), Nannyberry (*Viburnum lentago*), Michigan Holly (*Ilex verticillata*), and shrubby dogwoods (*Cornus sericea*, *C. amomum*, and *C. foemina*). Graminoids are well-represented with numerous marshland sedges such as *Carex aquatilis*, *C. cristatella*, *C. gracillima*, *C. hystericina*, *C. lacustris*, *C. leptalea*, *C. pellita*, *C. stipata*, *C. stricta* and *C. vulpinoidea*. Other cyperaceous graminoids were Softstem Bulrush (*Schoenoplectus tabernaemontani*), Bulrush (*Scirpus atrovirens*), Wool-grass (*Scirpus cyperinus*), and two spike-rushes (*Eleocharis erythropoda* and *E. intermedia)*; wetland grasses, such as Bluejoint (*Calamagrostis canadensis*), Cut Grass (*Leersia oryzoides*), Fowl Manna Grass (*Glyceria striata*), Reed Manna Grass (*G. grandis*), and Wood Reedgrass (*Cinna arundinacea*) are also present. As would be expected in a marshy habitat, there was also an abundance of Marsh-marigold (*Caltha palustris*) and Skunk-cabbage (*Symplocarpus foetidus*).

Rare Plants and New County Records

Table 13 presents a list of species encountered in our field work that are significant because of their rarity status for the State of Michigan (Michigan Natural Features Inventory 2016). Because of the sensitivity of any state-listed plants with status of Threatened or Endangered, we have withheld locality data.

Boechera dentata: Threatened Status. This species was found growing along

TABLE 12. Species present for B. D. White Preserve—Southern Shrub-Carr Wetland. Total species richness: 131 spp.

Acer rubrum	*Galium aparine*	*Ranunculus hispidus*
Angelica atropurpurea	*Gaylussacia baccata*	*Ranunculus recurvatus*
Apios americana	*Geranium maculatum*	*Ribes americanum*
Asclepias incarnata	*Geum rivale*	*Ribes cynosbati*
Asclepias syriaca	*Glyceria grandis*	*Ribes hirtellum*
Athyrium filix-femina	*Glyceria striata*	*Rosa multiflora*
Berberis thunbergii	*Hackelia virginiana*	*Rosa palustris*
Bidens cernua	*Hamamelis virginiana*	*Rubus hispidus*
Boehmeria cylindrica	*Hypericum boreale*	*Rubus occidentalis*
Calamagrostis canadensis	*Hypericum punctatum*	*Rubus pubescens*
Caltha palustris	*Ilex verticillata*	*Rudbeckia laciniata*
Campanula aparinoides	*Impatiens capensis*	*Rumex obtusifolius*
Cardamine bulbosa	*Iris virginica*	*Sagittaria latifolia*
Carex aquatilis	*Juncus tenuis*	*Salix eriocephala*
Carex bebbii	*Lemna minor*	*Salix exigua*
Carex cephalophora	*Lonicera morrowii*	*Salix lucida*
Carex cristatella	*Lysimachia ciliate*	*Salix myricoides*
Carex gracillima	*Lysimachia thyrsiflora*	*Salix petiolaris*
Carex hystericina	*Micranthes pensylvanica*	*Salix sericea*
Carex lacustris	*Monarda fistulosa*	*Sambucus canadensis*
Carex leptalea	*Nasturtium microphyllum*	*Schoenoplectus tabernaemontani*
Carex pellita	*Onoclea sensibilis*	
Carex stipata	*Osmunda cinnamomea*	*Scirpus atrovirens*
Carex stricta	*Osmunda regalis*	*Scirpus cyperinus*
Carex vulpinoidea	*Packera aurea*	*Scutellaria lateriflora*
Chimaphila umbellata	*Parthenocissus quinquefolia*	*Solanum dulcamara*
Cinna arundinacea	*Pedicularis canadensis*	*Sphenopholis intermedia*
Cirsium muticum	*Pedicularis lanceolata*	*Spiraea alba*
Cornus amomum	*Persicaria amphibia*	*Stellaria longifolia*
Cornus foemina	*Persicaria hydropiper*	*Symphyotrichum puniceum*
Cornus sericea	*Persicaria pensylvanica*	*Symplocarpus foetidus*
Corylus americana	*Persicaria punctata*	*Taraxacum officinale*
Cryptotaenia canadensis	*Persicaria sagittata*	*Thelypteris palustris*
Cuscuta gronovii	*Phalaris arundinacea*	*Toxicodendron vernix*
Dasiphora fruticosa	*Physocarpus opulifolius*	*Typha latifolia*
Dioscorea villosa	*Platanthera psycodes*	*Ulmus americana*
Dryopteris cristata	*Poa alsodes*	*Vaccinium myrtilloides*
Eleocharis erythropoda	*Populus deltoides*	*Verbena hastata*
Eleocharis intermedia	*Populus tremuloides*	*Viburnum cassinoides*
Elymus hystrix	*Prunella vulgaris*	*Viburnum lentago*
Epilobium coloratum	*Prunus serotina*	*Viburnum opulus*
Epilobium parviflorum	*Pycnanthemum virginianum*	*Viola labradorica*
Equisetum arvense	*Quercus macrocarpa*	*Viola macloskeyi*
Eutrochium maculatum	*Ranunculus abortivus*	*Vitis riparia*

the edge of Floodplain Forest, in open shade with moist ground that was sparsely vegetated. Few plants were encountered. In Michigan, the species is known only from four counties, Kent, Ionia, Eaton, and Ingham, and few of the specimens are recent collections. In Kent County, most of the collections were made in the 1890s. Our collection is the first recent collection for Kent County, although Brad Slaughter (pers. comm.), as part of his fieldwork on endangered species for Michigan Natural Features Inventory, reported encounters with this plant at sev-

TABLE 13. State-listed rare plants encountered during this study and the listed status, collection number, and locality of each. Vouchers deposited at CALVIN and MICH.

Species	Listed Status	Collection Number	Locality
Boechera dentata	Threatened	*Stockdale, Abma, & Crow EC-16-1018*	Undisclosed
Carex davisii	Special Concern	*Leisman & Van Staalduinen EC-15-296; Stockdale & Abma EC-16-1436*	Lamberton Creek Mouth at Soldiers' Home Woods
Helianthus hirsutus	Special Concern	*Crow & Warners 10865; Leisman & Van Staalduinen EC-15-867*	Black Hills power line right-of-way
Lithospermum latifolium	Special Concern	*Crow 11090*	Mr. Lowes' Woods

eral localities in 2016. Cole (1901) indicated only two sites for this species; hence, it must have been rare in her day as well.

Carex davisii: Special Concern Status. This is a sedge of rich floodplain forests, occurring in only 11 counties in the southern portion of the state (MICHIGAN FLORA ONLINE 2011). The handsome cespitose sedge was found infrequently in well-shaded woods along the floodplain of a creek. Cole (1901) noted that it was "Rare in Mich.," citing only two localities southwest of the City along the Grand River between the old Glue Factory and the Salt Spring (sites that we have not been able to confidently locate as of yet). Four records of this species are known in Kent County (Warners et al. 2007), and four records in Ottawa County (MICHIGAN FLORA ONLINE 2011), two of which are from unpublished 2017 field work for this project.

Helianthus hirsutus: Special Concern Status. Hairy Sunflower is apparently a species of open dry woods and embankments (Voss and Reznicek 2012). In 2014 David Warners and Garrett Crow documented this species growing in an open area along power line right-of-way and adjacent to open Black Oak woods on the Black Hills. The site has a prairie-like landscape, dominated by *Andropogon gerardii*, *Panicum virgatum*, *Sorghastrum nutans*, *Solidago canadensis*, *Desmodium canadense*, *Lespedeza hirta*, *Rhus* spp. According to MICHGIAN FLORA ONLINE (2011) this species is documented from only six counties, however, Michigan Natural Features Inventory (2016) records indicate populations known from only 10 counties in the state.

Lithospermum latifolium: Special Concern Status. While trying to relocate *Hybanthus concolor*, another rare plant was encountered, American Gromwell. Ten clusters of robust plants, each with multiple stems, were found growing near the woodland paths, and a few other scattered individuals were also discovered.

Table 14 enumerates 20 species of plants that represent new county records for Kent County. Of these, 16 are adventive species, and some appear to be escapes from cultivation, including Grape-hyacinth (*Muscari botryoides*), Japanese Yew (*Taxus cuspidata*), Oregon-grape (*Berberis aquifolium*), and two handsome Mock-orange species (*Philadelphus coronarius* and *P. inodorus*). The robust Willow-herb (*Epilobium parviflorum*) appears to be a weedy species that

TABLE 14. New county records for Kent County. Vouchers deposited at CALVIN and MICH.

Species	Native or Adventive	Collection Numbers	Locality and Notes
Alnus glutinosa	Adventive	*Crow 11030; Stockdale & Abma EC-16-1129*	Old Soldiers Home/Lamberton Creek mouth. Old Soldiers Home/ Lamberton Creek mouth; on edge of creek (apparently escaped from cultivation).
Lonicera tatarica	Adventive	*Stockdale, Abma & Crow EC-16-993. Crow 10930; Stockdale, Abma & Crow EC-16-1015*	Old Soldiers Home/Lamberton Creek mouth. Lowes' Woods, springy, open woods, secondary growth.
Epilobium parviflorum	Adventive	*Stockdale EC-16-1516. Crow & Abma EC-16-1341; Stockdale & Abma EC-16-1419*	Old Soldiers Home/south woods; wet area, east edge. Lowell Township (BD White Preserve).
Euonymus alatus	Adventive	*Stockdale, Abma & Crow EC-16-1010*	Old Soldiers Home/south woods.
Euonymus fortunei	Adventive	*Leisman, Van Staalduinen & Crow EC-15-839, 840*	Old Soldiers Home/Lamberton Creek mouth.
Lapsana communis	Adventive	*Leisman, Van Staalduinen & Crow EC-15-318*	Old Soldiers Home/south woods.
Berberis aquifolium	Adventive	*Crow 11017*	Mill Creek, north portion (escaped from cultivation).
Taxus cuspidata	Adventive	*Crow 11010*	Mill Creek, bank of stream.
Muscari botryoides	Adventive	*Stockdale, Abma & Crow EC-16-1067*	Mill Creek, edge near RR bank.
Philadelphus inodorus	Adventive	*Stockdale & Abma EC-16-1141*	Mill Creek, south portion, high on bluff (escaped from cultivation).
Philadelphus coronarius	Adventive	*Stockdale, Abma & Crow EC-16-1254*	Mill Creek, near RR crossing (escaped from cultivation).
Ailanthus altissima	Adventive	*EC-16-1210*	Shadyside Park; a weedy tree.
Malus toringo[1]	Adventive	*Stockdale, Abma & Crow EC-16-1171*	Lowes' Woods; along outer edge of woods surrounding old farm pond; secondary growth.
Potentilla indica	Adventive	*Crow 10926; Stockdale, Abma & Crow EC-16-987*	Woods at base of ravine, north end.
Carex ormostachya	Native	*Crow & Warners 11112*	Lowes' Woods; clay soil, side of ravine in rich woods.
Rosa setigera	Native	*Stockdale & Abma EC-16-1392*	Lowes' Woods; wet woods at margin of old farm pond.
Scirpus hattorianus	Native	*Stockdale & Abma EC-16-1386*	Lowes' Woods; relatively undisturbed marshy area at north end where streamlets drain into wetland.

(*Continued on next page*)

[1]The illegitimate name *Malus sieboldii* Rehder is often applied to this species (Dickson 2014).

TABLE 14. New county records for Kent County. Vouchers deposited at CALVIN and MICH (*Continued).*

Species	Native or Adventive	Collection Numbers	Locality and Notes
Carex aggregata	Adventive	*Leisman & Van Staalduinen EC-15-111, EC-15-483*	Black Hills, south-facing slope along power lines.
Helianthus hirsutus	Native	*Crow & Warners 10865; Leisman & Van Staalduinen EC-15-867*	Black Hills, power line right-of-way.
Anthoxanthum odoratum	Adventive	*Stockdale & Abma EC-16-1271*	Lowell Township (B. D. White Preserve–Southern Dry Forest).

is spreading somewhat aggressively in wet habitats in Michigan, occurring in three of our sites. Its first occurrence in Michigan was recorded in 1966 (MICHIGAN FLORA ONLINE 2011), and it is now known from at least 18 counties.

Somewhat unusual is the first documentation from Kent County of a native wetland species, Mosquito Bulrush (*Scirpus hattorianus*), a relatively common species throughout Michigan. Kent County is rather well-collected, especially beginning with Emma Cole's (1901) *Flora* field work, but also by numerous field botanists working in the county since then. It is likely that this species had not been recorded previously, not only because of its similarity to *Scirpus atrovirens*, but also because Voss (1972) had previously included it within his concept of *S. atrovirens* (Voss and Reznicek 2012).

CONCLUDING REMARKS

Since those horse and buggy days when Emma Cole (1901) published her comprehensive *Grand Rapids Flora*, enormous changes have taken place within and around Grand Rapids that have impacted the botanical richness of our region. One of the primary goals of this project is to gain access to as many of the specific locations described by Cole as possible, evaluating their present-day status compared with her descriptions from 1901, as well as identifying and inventorying additional high-value natural landscapes within the Grand Rapids area. At times, rediscovering Cole's sites has been disappointing when we find little or no remaining natural habitat. Nevertheless, we have been encouraged when other historic sites are found that still retain levels of biodiversity and ecological integrity similar to what Emma encountered and wrote about. It is also deeply satisfying to happen upon ecological landscapes of very high value that were not known to Emma Cole and her colleagues and students (Jolman et al., submitted).

Yet, when development occurs—at least the kind of development that has happened in West Michigan over the past two centuries—degradation will be incurred by the natural landscapes in which development takes place. A primary

value of Emma Cole's work is that she established a baseline of information that allows us to more fully understand the changes, and particularly the losses incurred by the West Michigan landscape. Such a comparison is critical for the inhabitants of a given area to understand their own impact. Understanding what has been done (although seldom enjoyable) is a critical element for reconciling the human–nature relationship (Warners et al. 2014). Recognizing how unsustainable our existence has been in the past is a critical step in learning how to live more sustainably into the future.

Moreover, as we attempt to move forward into a more ecologically sustainable future, Cole's work provides important guidelines. Restoration ecologists emphasize the importance of having reliable reference communities as models for successful restoration projects (Galatowitsch 2012). Emma Cole's lists and site descriptions offer many historical reference communities that can give us guidelines for what degraded local habitats could once again become. Her work also provides a type of scorecard that allows us to evaluate whether preservation and conservation efforts are working.

Yet, our assessments clearly document a great deal of degradation. Several of Emma Cole's favorite collecting sites no longer support natural habitats (e.g., Burton Avenue Swamp, Plainfield Village Bluffs). And for sites that still remain, a comparison of present-day inventories with those generated from Emma Cole's work shows a consistent reduction in FQI values, indicating increased disturbance and a loss of native species over time. Using the Adjusted FQI in these comparisons provides additional evidence that non-native species have become more prevalent. These comparisons illustrate that, while setting aside natural areas is critical for protecting native biodiversity, remnant natural areas will tend to experience a decline in native biodiversity if they are not actively managed, especially when the remnants are small and isolated (Powell et al. 2011, Latombe et al. 2018).

So, while our research is identifying some of the high-quality natural areas that still remain in the Grand Rapids Region, these oases for native biodiversity appear to be slowly declining in quality due to their small size, isolation, and the ongoing influence of invasive non-native species. The native species in these remnants are also likely declining in genetic diversity due to their loss of connectivity with other such natural habitats (Luque et al. 2012, Frankham 2015). The species we are discovering to be rare elements in these remnant habitats are almost certainly in the midst of severe bottleneck events, considering how many changes have impacted the landscape since European settlement began. Other rare species documented by Cole that we have not been able to find (such as *Hybanthus concolor* and *Hydrastis canadensis* mentioned in this paper) have likely been lost from our region. Since we have so few high-quality natural areas left, and since many native species continue to decline, it is paramount that we protect and maintain the remnants that still exist. The hard work of preservation, management, and restoration will be needed if the kind of biodiverse landscapes that Emma Cole and her students documented are to be securely passed along for future generations to experience and enjoy.

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RELATIVE INFLUENCE OF SPATIAL AND STRUCTURAL CHARACTERISTICS OF FOREST FRAGMENTS ON WOODY PLANT COMMUNITIES

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ABSTRACT

In the southern Great Lakes region, forests have become fragmented into small, privately owned woodlots surrounded by an agricultural matrix. Due to their small size, these forests typically have a high edge to interior ratio, resulting in influence on them by the surrounding agricultural matrix. We surveyed thirty forest fragments in Adams, Allen, and Wells Counties, Indiana, identifying understory and midstory woody plants to species in 25-m^2 plots. Spatial characteristics of the forest (perimeter, area, shape, and isolation) and environmental characteristics (soil moisture, canopy cover, age, basal area, and overstory species diversity) were quantified. Forests were categorized into four size classes (≤5, 5–10, 10–15, > 15 ha, each inclusive of upper size limits). There were no significant differences between size classes in shape, isolation, or environmental characteristics, except for overstory richness and diversity. Overstory diversity added significantly to understory and midstory richness and diversity in multiple regression models. Additionally, overstory diversity, forest shape, and soil moisture were included variables in visualizing community composition with non-metric multidimensional scaling (NMDS). Many of the surveyed forests were some variant of *Acer saccharum* forest types. The forests in the region are second-growth forests, having been harvested at some point in their history. Our survey sites were experiencing regeneration, with recruitment into larger size classes from understory to midstory. While they are not old-growth forests, these fragments do provide forest functions and habitat for numerous species within an agricultural matrix. Future management should focus on engaging land owners in cooperative decisions to promote forest sustainability in the region.

KEYWORDS: diversity, fragmentation, richness, harvest, management

INTRODUCTION

In the Midwest region of the United States, areas historically forested have been converted to agricultural, suburban, and urban development (Meehan et al. 2011; Ritters et al 2012). In the northern Great Lakes region, agriculture land cover has remained fairly constant over several decades at approximately 37% of land cover (Brown 2003), whereas in the southern Great Lakes region, cultivated and pasture agriculture lands account for 70% or more of land cover (Meehan et al. 2011). Forests have been fragmented into woodlots that are small and often privately owned. These woodlots typically were retained because of their lack of agricultural suitability and productivity (Medley et al. 1995). Due to their small size, these forest fragments often have a high edge to interior ratio, thereby in-

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creasing influence of the surrounding agricultural land matrix upon the forest itself (Ewers et al. 2007; Gonzalez et al. 2010; Tanentzap et al. 2010).

Forest fragmentation inserts a new matrix into the landscape, which modifies landscape variability, segregates environmental conditions, and has variable impact on the biota depending on taxonomic grouping. By inserting a new matrix, habitat is lost, which can lead to negative population growth rates for numerous species, reduced dispersal success, and decreased specialist species richness (e.g. Donovan and Flather 2002; Fahrig 2003). Changes can be seen at the individual, population, and ecosystem levels. While there is evidence of negative influence on species from a variety of taxa, species that are highly mobile (e.g., mammals, birds, insects, early-successional plants), generalist predators, and long-lived species often display positive responses in population growth and dispersal (Debinski and Holt 2000).

Due to successional processes and the persistence of woody species in juvenile size classes, we can observe the potential successional pathway and trajectory of a forest (Oliver and Larson 1996). Fragmentation may alter the successional pathway, and, as a result, species diversity. By quantifying the physical and compositional structure of the forest, we can gain an understanding of the future forest. Applying classical island biogeography theory proposed by MacArthur and Wilson (1967), we would anticipate that larger, less isolated, and older forest fragments would contain more species. We would also expect there to be an association between overstory composition and structure and understory richness. The objective of this study was to identify the relative influence of forest fragment size, shape, isolation level, age, past management, connection to other forests and overstory composition on the understory and midstory woody plant communities.

MATERIALS AND METHODS

Forest fragments surrounded by an agriculture matrix were identified in the study region of northeast Indiana, specifically in northern Adams, southeastern Allen, and eastern Wells Counties (Figure 1). These counties, which have relatively sparse populations (0.34 people/ha), were historically dominated by hardwood forests that have been converted into row crop and pasture fields, creating fragmented and isolated forests (Homoya et al. 1985).

A random, stratified sample of 30 suitable forest fragments was categorized into four size classes (≤5, 5–10, 10–15, >15 ha, each inclusive of the upper limit values). A fragment was considered suitable for this purpose if it was physically accessible with permission from individual land owners and was surrounded by agriculture. For purposes of this study, woody plants were classified as understory (plants < 2 m height), midstory (plants ≥2 m height and < 8 cm dbh), and overstory (plants ≥8 cm dbh), where dbh is diameter at breast height (1.3 m above soil the surface). Plant surveys taken in randomly selected 25-m^2 plots (5 m × 5 m) in each forest fragment were performed from June to August 2013. Plots were visited once each during the survey period and randomly selected using the Sample Design Tool for ArcGIS (version 10.1, ESRI Inc., Redlands, California). The plots were located on a 25.6 m spaced grid, excluding a 25.6 m edge buffer, and minimum plot number increasing with size class (≤5 ha, n = 5 plots; 5–10 ha, n = 6; 10–15 ha, n = 6; >15 ha, n = 12). Within each plot, all individual understory woody plants and midstory woody plants were counted and identified to species.

All individual overstory woody plants within a 500 m^2 circular plot (12.62 m radius) centered on the understory and midstory plots were identified to species and their dbh was measured. The basal area (m^2/ha) of each species in the overstory was calculated from dbh values. Environmental characteristics measured within each 25 m^2 plot included volumetric soil moisture content (percentage

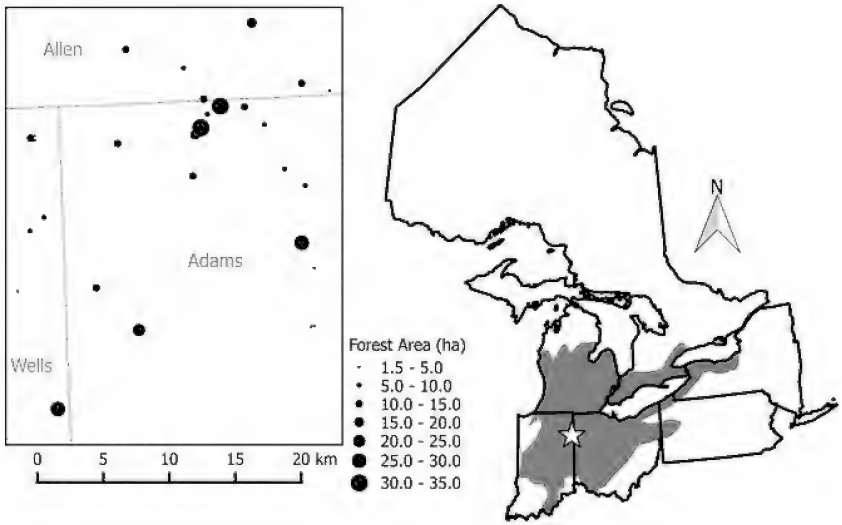

FIGURE 1. Southern Great Lakes forest region (shaded; map adapted from Barrette 2010; data on extent of the forest from Ricketts et al. 1999), with star indicating general study site area. The inset shows the location and size class for each of the forest fragments in this study in Adams, Allen, and Wells Counties, Indiana. Size classes inclusive of the upper limits. Map licensed under, and subject to, Creative Commons Attribution-Share Alike 3.0 license.

using a FieldScout TDR meter manufactured by Spectrum Technologies, Inc., of Aurora, Illinois) and percentage forest canopy cover (using a concave spherical densitometer obtained from Forestry Suppliers in Jackson, Mississippi). To determine forest age, an increment borer was used to core the largest tree within each overstory plot, excluding those identified by the landowner as a high-value hardwood species. Simple ring counting was used to age trees and to act as a surrogate for forest age.

The perimeter and area of the forest fragment, its distance to the nearest forest fragment in each cardinal direction, and (as a surrogate for isolation) the total number of forests within each of a 1 km and 2 km radius were calculated for each forest fragment using ArcMap (version 10.1, ESRI Inc., Redlands, California). The shape was calculated for each forest as perimeter / $(2 \times (\text{area} \times \pi)^{1/2})$, where increasing values represent an increasingly complex or irregular shape (Hill and Curran 2003; Patton 1975). Forest types were defined according to Eyre (1980) by the three overstory species with the highest relative importance values (RIV) in the forest, where:

RIV = (relative frequency + relative density + relative dominance) / 3;
relative frequency = 100 × species frequency / sum of all species frequencies;
species frequency = number of plots in which a species occurred / number of plots surveyed;
relative density = 100 × number of individuals of a species per ha / number of all individuals per ha; and
relative dominance = 100 × total basal area of a species / total basal area of all species.

For each forest fragment, understory and midstory species richness and diversity (as Shannon index) were calculated (Hayek and Buzas 1997). For each species in the understory and midstory, the rank relative abundance (= species abundance / sum of species abundances in each stratum individually) were calculated in each forest and plotted to visually compare evenness between forest fragments and size classes.

Analysis of variance (ANOVA) with a Tukey's HSD post-hoc test was used to compare the four

forest size classes with respect to nearest fragment, isolation, canopy cover, volumetric soil moisture content, age, basal area, as well as richness and diversity for each of the three strata. Multiple regression with reverse variable selection was used to test for relationships between understory and midstory community measures (species richness, diversity) and environmental variables at the forest level with collinear variables removed when necessary. Past management was defined for each forest, which was provided by landowners. Forests that were selectively harvested in the last 20 years were categorically marked as "harvested." This included six of the thirty forests, two owned by forest products companies and four by individual owners at the time of the harvest. Harvested versus non-harvested forest fragments were used as an environmental variable in calculations. T-tests were performed comparing harvested and non-harvested forests to forest spatial and environmental factors (basal area, overstory richness and diversity, area, perimeter, ratio of perimeter to area, canopy cover, soil moisture, forest age, distance to nearest neighbor, and forest neighbor counts in 1 km and 2 km radii).

Non-metric multidimensional scaling (NMDS) ordination was used to visually compare understory and midstory species counts at the forest level. NMDS ordination was performed for species level analysis, creating species space of abundance of the understory and midstory based on Bray-Curtis dissimilarity between forests. Significant environmental variable influences on species distribution were plotted as directional vectors. All statistical analyses were conducted with $\alpha = 0.05$ (for NMDS vector selection $\alpha = 0.1$) using R base and vegan packages (R Core Team 2015; Oksanen et al. 2016).

RESULTS

Perimeter and area were not compared between size classes as area was the defining characteristic for classes and perimeter is positively correlated with area. None of the spatial characteristics were significantly different between the forest size classes (Table 1). Furthermore, there were no significant differences between the forest size classes with respect to canopy cover, volumetric soil moisture content, estimated age, or overall basal area (Table 2). Overall, these

TABLE 1. Mean spatial characteristics of forest fragments by size class. Count is the number of forest fragments surveyed in each size class. Shape is calculated as Perimeter / (2 * (Area *)½), Nearest is the mean distance to the nearest forest fragment and isolation is given as the total number of forests within 1 km and within 2 km, respectively. Standard errors are in parentheses.

Size Class	Count	Perimeter (km)	Area (ha)	Shape	Nearest (km)	Isolation 1 km	Isolation 2 km
≤ 5 ha	8	0.72 (0.17)	3.2 (0.5)	0.134 (0.018)	1.24 (0.60)	5.8 (0.8)	19.9 (1.4)
5–10 ha	7	1.17 (0.06)	7.0 (0.5)	0.125 (0.004)	0.68 (0.06)	6.0 (0.8)	19.1 (1.3)
10-15 ha	8	1.84 (0.15)	13.1 (0.5)	0.143 (0.010)	1.70 (1.09)	5.8 (0.9)	19.0 (1.6)
> 15 ha	7	2.84 (0.27)	25.0 (2.7)	0.162 (0.013)	0.59 (0.07)	6.9 (0.7)	20.4 (1.7)
$F_{3,26}$ (p-value)				1.41 (0.264)	0.61 (0.615)	0.38 (0.770)	0.19 (0.900)

TABLE 2. Mean canopy cover (percentage), mean volumetric soil moisture content (percentage; VMC), mean age in years, mean basal area (m^2/ha), and richness and diversity for understory, midstory, and overstory strata for each forest size class. Standard errors are in parentheses. Significant ANOVA results are indicated with an asterisk (*). Unique letters (in superscripts) indicate significant differences with Tukey's HSD.

Size Class	Canopy Cover	VMC	Age	Basal Area	Understory		Midstory		Overstory	
					Richness	Diversity	Richness	Diversity	Richness	Diversity
≤5 ha	90.10 (2.39)	35.44 (6.28)	40.69 (4.80)	16.11 (2.39)	13.38 (1.27)[a]	2.15 (0.14)	8.38 (0.96)	1.36 (0.12)	9.38 (0.92)[a]	1.73 (0.08)[a]
5–10 ha	89.25 (2.68)	40.97 (4.41)	37.10 (3.94)	16.96 (2.16)	16.86 (0.67)[ab]	2.36 (0.07)	9.43 (1.43)	1.45 (0.18)	12.43 (0.87)[ab]	2.01 (0.08)[ab]
10–—15 ha	91.32 (1.74)	47.56 (6.26)	45.45 (3.83)	17.46 (1.76)	16.50 (0.65)[ab]	2.31 (0.08)	6.75 (1.19)	1.71 (0.11)	12.13 (0.67)[ab]	2.05 (0.07)[b]
> 15 ha	89.71 (1.92)	54.75 (4.82)	43.36 (2.90)	18.75 (1.82)	17.71 (1.57)[b]	2.25 (0.16)	8.00 (0.62)	1.46 (0.14)	12.86 (1.01)[b]	1.88 (0.08)[ab]
$F_{3,26}$ (p-value)	0.16 (0.920)	2.13 (0.120)	0.80 (0.504)	0.25 (0.862)	3.04 (0.047)*	0.59 (0.626)	1.03 (0.397)	1.32 (0.290)	3.39 (0.033)*	3.39 (0.033)*

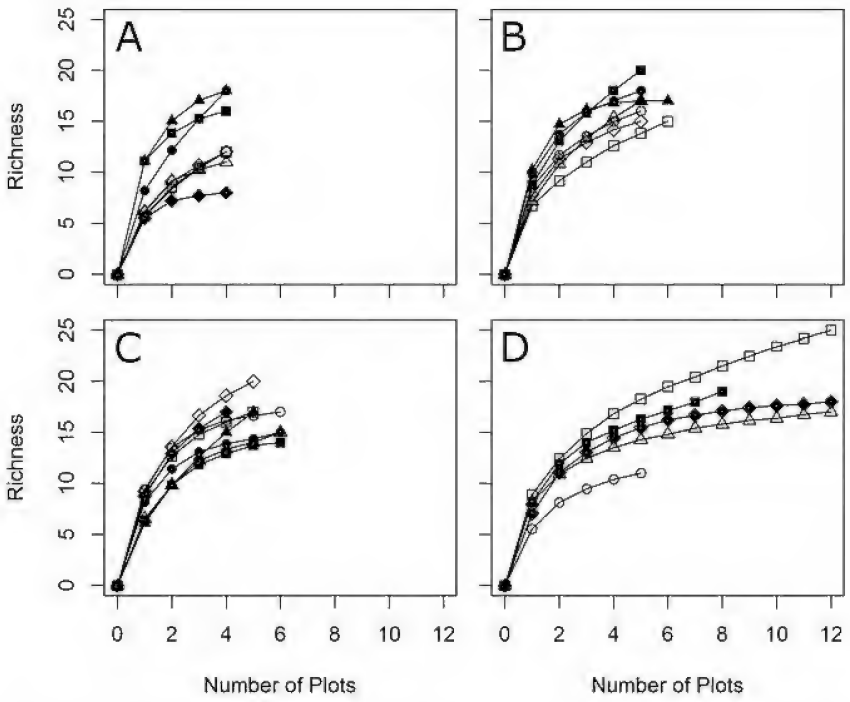

FIGURE 2. Understory species accumulation curves for the thirty forests surveyed in each of the four size classes of ≤5 ha (A), 5–10 ha (B), 10–15 ha (C), and > 15 ha (D).

sites were relatively closed canopy (canopy cover = 90.1%), are most likely second-growth (age = 41.7 years [a rather conservative measure of age]; basal area = 17.3 m^2/ha), and relatively mesic (volumetric soil moisture content = 44.5%).

A total of 41 understory species in 23 families were encountered within the 30 forest fragments surveyed (Appendix I). Vines (*Parthenocissus quinquefolia* and *Vitis riparia*) occurred in 29 of the forests, with *P. quinquefolia* occurred relatively frequently in each of those forests (Appendix I). In many of the forest fragments, the understory species accumulation curves began approaching asymptotes (Figure 2). There were exceptions to this in a few forests in each of the ≤5 ha, 5–10 ha, and 10–15 ha size classes (Figure 2A–C). The smallest size class (≤5 ha) had significantly lower understory richness compared to the largest size class (> 15 ha) ($F_{3,26}$ = 3.04, p = 0.047). However, there were no other differences between forest size classes. In addition, there were no significant differences in diversity between the size classes ($F_{3,26}$ = 0.59, p = 0.626). There were no significant differences in species richness or diversity between forests with and without harvesting within the last 20 years ($t_{(2),28}$ = –1.52, p = 0.140; $t_{(2),28}$ = –1.14, p = 0.263; respectively). Slopes for the mean rank relative abundances were used as a surrogate for species evenness and appear to be similar between

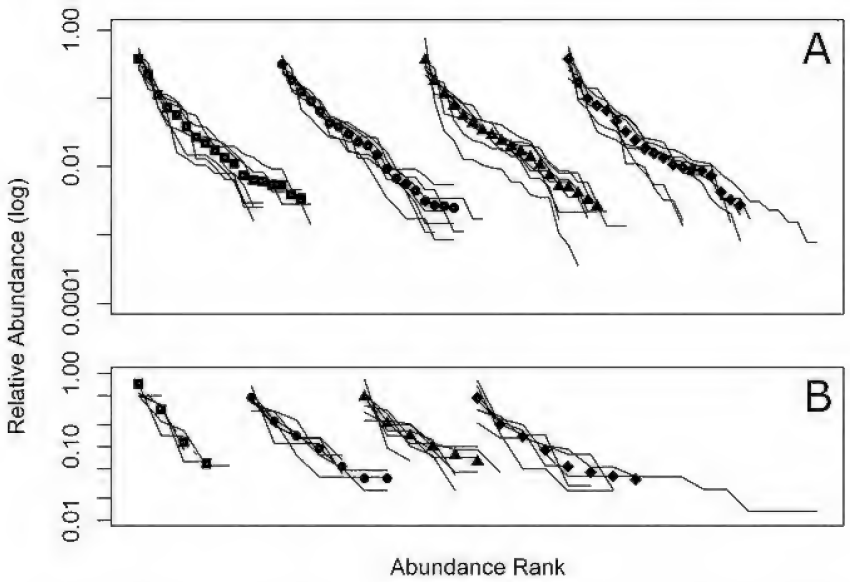

FIGURE 3. Rank relative abundance curves for understory (A) and midstory (B) species for forest size classes. Lines represent individual forests in each size class and symbols represent mean values for the size class (square: ≤ 5 ha; circle: 5–10 ha; triangle: 10-15 ha; diamond: > 15 ha). Mean values were calculated for a minimum of three forests in each size class.

forest size classes (Figure 3A). In testing relationships between understory species richness and the forest spatial and environmental characteristics via multiple regression, forest shape, perimeter, and overstory diversity were retained through reverse variable selection, where

$$\text{understory richness} = 8.69 + 5.22 \times \text{OverstoryDiversity} + 0.002 \times \text{Perimeter} - 0.044 \times \text{Shape} \ (F_{3,26} = 6.51,\ p = 0.002,\ R^2 = 0.43).$$

Understory diversity had a simpler model:

$$\text{understory diversity} = 1.78 - 0.02 \times \text{BasalArea} + 0.47 \times \text{OverstoryDiversity} \ (F_{2,27} = 3.65,\ p = 0.041,\ R^2 = 0.23).$$

A total of 27 midstory species in 14 families were encountered within the 30 forest fragments (Appendix II). The mean number of midstory species was 8.1 (range: 3–17), and *Acer rubrum* was the most frequent species, occurring in 23 forests (Appendix II). *Acer saccharum* was the second most frequent species, occurring in 21 forests (common in 2/3 of those forests; Appendix II). Midstory species richness and diversity did not differ significantly between the size classes ($F_{3,26} = 1.83$, $p = 0.166$; $F_{3,26} = 1.316$, $p = 0.290$; respectively). As with the understory, there were no significant differences in species richness or diversity between forests with and without harvesting within the last 20 years ($t_{(2),28} = -1.80$, $p = 0.082$; $t_{(2),28} = -0.81$, $p = 0.423$; respectively). Slopes for the mean rank rel-

ative abundances were similar between forest size classes (Figure 3B). Midstory species richness had a different multiple regression model than the understory richness, where

$$\text{midstory richness} = -22.71 + 6.45 \times \text{OverstoryDiversity} + 0.12 \times \text{Area} + 0.19 \times \text{CanopyCover} \ (F_{3,26} = 11.54,\ p < 0.001,\ R^2 = 0.57).$$

Midstory species diversity also had a different model from the understory counterpart, where

$$\text{midstory diversity} = -2.34 + 1.13 \times \text{OverstoryDiversity} + 0.02 \times \text{CanopyCover} \ (F_{2,27} = 16.70,\ p < 0.001,\ R^2 = 0.55).$$

In all four multiple regression equations (two strata and two measures of diversity), overstory diversity had a significant positive influence on the resulting dependent variable. In comparing standardized beta values within each multiple regression, overstory diversity contributed the most to the midstory richness and diversity regression equations, and overstory diversity contributed the least for the understory richness and diversity regression equations.

A total of 31 overstory species in 12 families were encountered within the 30 forest fragments (Appendix III). The mean number of overstory species was 11.6 (range: 7–18). *Ulmus americana* was the most frequent overstory species, occurring in all 30 forests (frequent or common in 2/3 of those forests; Appendix III). However, it was the most important species (i.e., the one having the greatest relative importance value) in only five forests. Additionally, *Acer saccharum*, *Carya ovata*, and *Ostrya virginiana* had a high frequency of occurrence in 26 forests, with *A. saccharum* being most important in 12 forests (common in nearly 60% of those forests; Appendix III). Based on the three species with the highest relative importance values, forest types were identified for each fragment (Table 3). *Acer saccharum* was a defining overstory species in 53.3% of the forests.

Using non-metric multidimensional scaling (NMDS) ordination, we visually aligned sites based on understory community composition (Figure 4A). The understory NMDS analysis had a final stress of 0.23, with two dimensions, and was plotted with vectors which had significant relationships with the communities. Forest shape had a long vector, indicating a strong influence on community composition, with overstory diversity (overDiv) vector pointing in the opposite direction (Figure 4A). Additionally, we aligned sites based on midstory community composition via NMDS (Figure 4B). The midstory NMDS analysis had a final stress of 0.19 with two dimensions (Figure 4B). While the presence of harvest events within the past 20 years did not add to the linear models for richness or diversity, it aligned with the NMDS plot for midstory (Figure 4B).

DISCUSSION

The landscape of northeastern Indiana was historically continuous forest, but has been modified to agricultural use through anthropogenic actions (Homoya et

TABLE 3. Forest types of the survey sites based on the three overstory species with the highest relative importance values. The forest fragments are numbered within each county, where AD = Adams County, AL = Allen County, and W = Wells County.

Forest Fragment	Forest Type
AD01	Red Maple
AD02	Sugar Maple
AD03	Sugar Maple–Basswood
AD04	Sugar Maple
AD05	Sugar Maple–Basswood
AD06	Cottonwood
AD07	Black Oak
AD08	White Ash–American Elm–Red Maple
AD09	Beech–Sugar Maple
AD10	Silver Maple–American Elm
AD11	Sugar Maple
AD12	Red Maple
AD13	Sugar Maple
AD14	Sugar Maple
AD15	Black Oak
AD16	Sugar Maple
AD17	Sugar Maple
AL01	White Oak
AL02	Sugar Maple–Basswood
AL03	Sugar Maple–Basswood
AL04	Beech–Sugar Maple
AL05	Beech–Sugar Maple
AL06	River Birch
W01	Cottonwood
W02	Black Oak
W03	Black Oak
W04	Cottonwood
W05	Sugar Maple
W06	Beech–Sugar Maple
W07	Red Maple

al. 1985). Such dramatic changes in land coverage leads to substantial modifications in hydrology, carbon and nitrogen cycling, and wildlife distributions (e.g. Mao and Cherkauer 2009; Murty et al. 2002; Pimm and Askins 1995). Forests in northeastern Indiana are relatively small and isolated with no large neighboring forests. Even with the mass conversion of land cover types in the southern Great Lakes region, forest cover has increased typically under private ownership but not under management by a larger non-profit or government agency (Brown 2003).

Across all our study forests, the mean distance to the nearest forest fragment was approximately 1 km (median = 0.6 km). Additionally, there was a mean of 6 forests within 1 km and nearly 20 forests within 2 km for our sites. This level of isolation was consistent across all four size classes. Our selection protocol likely did insert some bias into the isolation measures, as we focused on a study area dominated by agriculture with minimal urban/suburban development and on forests as stand-alone units. However, this is the landscape present in the region, in which many forests are privately owned and are surrounded by an agricultural

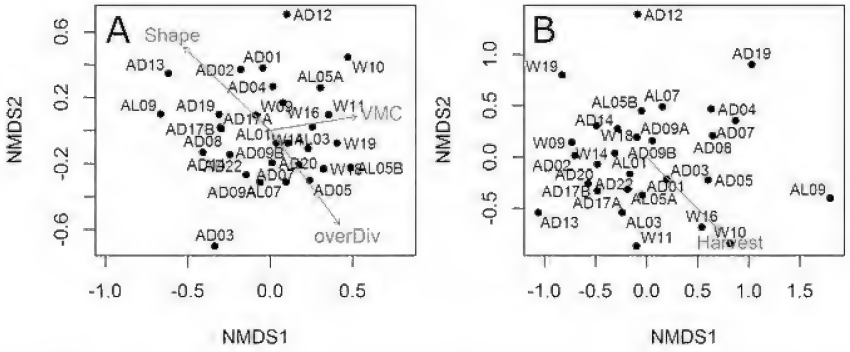

FIGURE 4. Non-metric multidimensional scaling (NMDS) ordination plots for understory (A) and midstory (B) communities. Site prefixes indicate county (AD = Adams; AL = Allen; W = Wells). Distances calculated as Bray-Curtis dissimilarity. Length and direction of vectors indicates strength and orientation of forest characteristic influence (overDiv = Shannon diversity index of overstory species; Shape = ratio of perimeter to area; VMC = volumetric soil moisture content; Harvest = harvesting event within past 20 years).

matrix (Brown 2003; Homoya et al. 1985). Additionally, there are relatively large gaps between forests that are filled with agricultural land cover matrix that must be traversed for tree species to colonize or interact reproductively.

Despite similarities in all of the environmental and spatial characteristics, there were still differences between the smallest and largest size classes in understory richness and overstory richness. Classical island biogeography would explain that differences in richness were likely due to larger islands of habitat inherently having more species as a result of environmental heterogeneity and greater niche space (Hannus and von Numers 2008). However, our measured environmental variables were not significantly different between the forest fragment size classes. Other environmental variables, such as slope, nutrient content, and wind speed, which were not included in our study, likely influence dispersal and establishment. Furthermore, the larger forests had a greater interior area that is less influenced than the interior of smaller forests by the surrounding agricultural matrix, thereby allowing certain specialist to persist when they would not in smaller forests more heavily affected by the agricultural matrix, e.g. *Aesculus glabra*, *Lindera benzoin*, *Staphylea trifolia*, and *Quercus alba* occurred more often in our understory data in the larger two size classes than the smaller two classes (Harris 1984).

For both understory and midstory species richness and diversity, overstory diversity was an influential environmental characteristic. In all four multiple regression models overstory diversity had a positive influence on the other strata. Cook (2015) argued that undue management emphasis has been placed on overstory layers and more focus should be paid to lower strata in making management decisions. While the analyses between the two studies are different, our results do not align with those of Cook (2015) in that we found structural and environmental characteristics influencing understory and midstory strata. In our

multiple regression analyses, overstory diversity and basal area were influential in defining understory diversity. Additionally, overstory diversity was also a directional vector in the NMDS for understory communities. There is a clear connection between strata and a positive influence by the overstory on lower strata in hardwood forests (e.g. Roberts 1992; Frelich and Reich 1995; Neuendorff et al. 2007).

Even though our site selection was random from sites that were accessible (visually from aerial images) and were accompanied by land owner permissions, we had a large proportion of sites dominated by *A. saccharum*. This is expected for the region where *A. saccharum* is a common stand-defining species, dominating many forest fragments, especially sites with fairly mesic soils (Arvola et al. 2014; Brothers and Spingarn 1992). This also may be related to similar origins, that is, forests retained due to low agricultural productivity (Medley et al. 1995). While our focus was on woody species, Fuelling (2014) did report several species with relatively high coefficient of conservatism values (>7), including *Fagus grandifolia* and *Quercus bicolor* reported here. Coefficient of conservatism is a relative measure of preference by a species for undisturbed habitat, i.e., high values represent those found in pre-settlement remnant habitat (Rothrock 2004; Rothrock and Homoya 2005). More than 75% of the species reported by Fuelling (2014) in these same forests had coefficient of conservatism values less than six, suggesting that these forests are still displaying effects of disturbance.

The forest fragments selected for this study exemplify forests within northeastern Indiana. Apart from Ouabache State Park in Wells County, which is second-growth forest with visible remnants of past disturbances (personal observation), there are no large forests in our study area (our largest surveyed forest was 33.5 ha). Rather, this region of the state is left with only small, isolated forest fragments that dot the landscape. The only large forests in Indiana with any measurable "core" (i.e. interior >600 m from edge) exist in the southern third of the state (Spetich et al. 1997). As such, the forests in our study are likely heavily influenced by edge habitat with little or no true core (Ewers et al. 2007). These fragments nevertheless provide necessary habitat in the region. Even with fragmentation, there may be benefit in protecting the forests that do exist as subdivisions of habitat (Harris 1984; Quinn and Harrison 1988). Regeneration is occurring as seedlings and saplings are being recruited into large size classes. Although they are not old-growth forests, they are functional second-growth forests. Given that these forest fragments are our only remnants of what once was continuous forests coverage, efforts should be made to engage land owners in management decisions that can promote the sustainability of the forests.

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APPENDIX I. List of understory species encountered in studied forests. Nomenclature follows Integrated Taxonomic Information System (2018). Species names are followed by collection number (when available). Forest code prefixes indicate county (AD = Adams County, AL = Allen County, W = Wells County). For each forest, relative occurrence was categorized as R (rare [one or two occurrences]), O (occasional [sporadic occurrence]), F (frequent [widespread throughout]), and C (common [dominant in community]). Voucher specimens were deposited by R. R. Harman in the Purdue University Fort Wayne, Department of Biology herbarium.

Species	AD01	AD02	AD03	AD04	AD05	AD06	AD07	AD08	AD09	AD10	AD11	AD12
Acer negundo L. (13)	R				O					O		
Acer rubrum L. (02)	C	C	F	O	O	O	O	O	O	O	O	O
Acer saccharinum L. (23)			R		O	R						
Acer saccharum Marsh. (04)	F	C	F	F	O	O	O	F	F		R	C
Aesculus glabra Willd. (38)				O		O						
Carpinus caroliniana Walter (21)			O		O	O		O	O			
Carya cordiformis (Wangenh.) K. Koch (20)		O	O	O	O	O	R	O	O	O	O	O
Carya ovata (Mill.) K. Koch (27)					O	O	R	R	O			
Celtis occidentalis L. (40)												
Cephalanthus occidentalis L. (07)	O	O			O	O	O					
Cornus drummondii C.A. Mey. (34)							O			O	O	
Cornus racemosa Lam. (33)							O					
Crataegus mollis (Torr. & A. Gray) Scheele (08)	O		R			R		O		R		
Fagus grandifolia Ehrh. (28)		O		O	O	R	O	R	O			O
Fraxinus americana L. (05)	O	O	O	F	O	O	O	O	O	O	F	F
Fraxinus pennsylvanica Marsh. (03)	F	O	O	O	O	O	O	O	O	R		O
Gleditsia triacanthos L. (16)	R		R									
Lindera benzoin (L.) Blume (25)				O	F	F		R	O			O
Liriodendron tulipifera L. (32)					R							
Nyssa sylvatica Marshall (19)			O		O			O				
Ostrya virginiana (Mill.) K. Koch (26)					O		O		O			F
Parthenocissus quinquefolia (L.) Planch. (01)	C	O		C	C	C	C	C	C	C	C	F
Platanus occidentalis L. (41)												
Populus deltoides W. Bartram ex Marshall (18)	R	R				O						
Populus grandidentata Michx. (36)							R				R	
Prunus serotina Ehrh. (22)			R									

(*Continued next page*)

APPENDIX I. (*Continued*)

Species	AD13	AD14	AD15	AD16	AD17	AL01	AD02	AD03	AD04	AD05	AD06	W01
Acer negundo L. (13)				O	R							
Acer rubrum L. (02)	C	C	O	O	O	O		O	R	O		O
Acer saccharinum L. (23)			R									
Acer saccharum Marsh. (04)	F	F	O	C	F	O	F	O	O	F		O
Aesculus glabra Willd. (38)									R			
Carpinus caroliniana Walter (21)				O		O	O		O	O		
Carya cordiformis (Wangenh.) K. Koch (20)	O	O	O	O	O	O	O	O	O	O	O	F
Carya ovata (Mill.) K. Koch (27)				O	O	O	O	O	O	R		O
Celtis occidentalis L. (40)												
Cephalanthus occidentalis L. (07)						O	O	O	O		O	O
Cornus drummondii C.A. Mey. (34)												
Cornus racemosa Lam. (33)												
Crataegus mollis (Torr. & A. Gray) Scheele (08)					R	O						
Fagus grandifolia Ehrh. (28)	R	R		O					R	O		
Fraxinus americana L. (05)	O	O	O	O	O	O	O	O	O	O	O	F
Fraxinus pennsylvanica Marsh. (03)	O	O	O	F	R	O	C	O	O	O	O	O
Gleditsia triacanthos L. (16)			R								O	
Lindera benzoin (L.) Blume (25)				O	R	O	O	O	C	F		O
Liriodendron tulipifera L. (32)												O
Nyssa sylvatica Marshall (19)												
Ostrya virginiana (Mill.) K. Koch (26)	O	O			O	O	O			R		O
Parthenocissus quinquefolia (L.) Planch. (01)	C	C	C	F	C	O	F	O	C	C	C	C
Platanus occidentalis L. (41)									O			
Populus deltoides W. Bartram ex Marshall (18)				O	O				O			O
Populus grandidentata Michx. (36)												
Prunus serotina Ehrh. (22)												

Species	W02	W03	W04	W05	W06	W07
Acer negundo L. (13)					O	
Acer rubrum L. (02)	O	O	F	O	F	O
Acer saccharinum L. (23)						
Acer saccharum Marsh. (04)		O	C	O	F	O
Aesculus glabra Willd. (38)		R		O		
Carpinus caroliniana Walter (21)		R	O		O	O
Carya cordiformis (Wangenh.) K. Koch (20)	R	O	O	O	O	O
Carya ovata (Mill.) K. Koch (27)		O	O	R		O
Celtis occidentalis L. (40)		O				
Cephalanthus occidentalis L. (07)	F	O	O	O		O
Cornus drummondii C.A. Mey. (34)						
Cornus racemosa Lam. (33)						
Crataegus mollis (Torr. & A. Gray) Scheele (08)	R	R		O		
Fagus grandifolia Ehrh. (28)				O	R	
Fraxinus americana L. (05)		R	O	O	O	
Fraxinus pennsylvanica Marsh. (03)	O	O	O	F		O
Gleditsia triacanthos L. (16)	O					
Lindera benzoin (L.) Blume (25)	O	O	O		O	F
Liriodendron tulipifera L. (32)						
Nyssa sylvatica Marshall (19)						
Ostrya virginiana (Mill.) K. Koch (26)		O	O	O	O	O
Parthenocissus quinquefolia (L.) Planch. (01)	F	C	F	F	F	F
Platanus occidentalis L. (41)						
Populus deltoides W. Bartram ex Marshall (18)			R			
Populus grandidentata Michx. (36)						
Prunus serotina Ehrh. (22)						

(*Continued next page*)

APPENDIX I. (*Continued*)

Species	AD01	AD02	AD03	AD04	AD05	AD06	AD07	AD08	AD09	AD10	AD11	AD12
Quercus alba L. (35)				O					R			
Quercus bicolor Willd. (29)					R							O
Quercus rubra L. (10)	O	R		O	O	R			R	R		
Quercus velutina Lam. (39)												
Rhamnus cathartica L. (12)	O		O		R		R					
Ribes cynosbati L. (15)	R		O		O	F	O	O	O		O	O
Rosa carolina L. (11)	O	R		O					R	O	O	
Rubus allegheniensis Porter (17)	R	O	C	O	O	O	O	O	O	R	O	O
Smilax ecirrhata (Engelm. ex Kunth) S. Watson (24)			R		O							
Staphylea trifolia L. (37)												
Tilia americana L. (31)					R							
Toxicodendron radicans (L.) Kuntze	O		F	O	O	O	C	F	O	C	O	O
Ulmus americana L. (14)	R		O	O	O	O	O	O	R		O	O
Ulmus rubra Muhl. (06)	O				O	O	R	O	O	O		
Vitis riparia Michx. (09)	O	O	O	O	O	O	O	O	O	O	O	R

Species	AD13	AD14	AD15	AD16	AD17	AL01	AL02	AL03	AL04	AL05	AL06	W01
Quercus alba L. (35)				O	R		O	O		O		
Quercus bicolor Willd. (29)							O	O				
Quercus rubra L. (10)							O	O				O
Quercus velutina Lam. (39)												
Rhamnus cathartica L. (12)												
Ribes cynosbati L. (15)	O	O	O	O	O		O	O	R		O	O
Rosa carolina L. (11)					O			O	O	R		
Rubus allegheniensis Porter (17)	O	O	O	O	O	O	O	O	O	O	F	O
Smilax ecirrhata (Engelm. ex Kunth) S. Watson (24)												
Staphylea trifolia L. (37)										O		
Tilia americana L. (31)						R	O					
Toxicodendron radicans (L.) Kuntze	O	O	C	C	O	C	O	C	O	O	C	O
Ulmus americana L. (14)	R	R	R	O	O	R	O	R		O	R	O
Ulmus rubra Muhl. (06)			O	O					O	O		
Vitis riparia Michx. (09)	O	O	O	O	O	O	O	O	O	O		O

Species	W02	W03	W04	W05	W06	W07
Quercus alba L. (35)	O		R		R	
Quercus bicolor Willd. (29)	F	R		O		O
Quercus rubra L. (10)	R	R			R	R
Quercus velutina Lam. (39)	O					
Rhamnus cathartica L. (12)						
Ribes cynosbati L. (15)	O	O	O	O	C	O
Rosa carolina L. (11)	O	F	O	O	O	O
Rubus allegheniensis Porter (17)	O	O		O	O	
Smilax ecirrhata (Engelm. ex Kunth) S. Watson (24)						
Staphylea trifolia L. (37)						
Tilia americana L. (31)					R	O
Toxicodendron radicans (L.) Kuntze	C	F		F		C
Ulmus americana L. (14)			R		O	R
Ulmus rubra Muhl. (06)		R	O	O	O	O
Vitis riparia Michx. (09)	O	O	O	F	R	O

APPENDIX II. List of midstory species encountered in studied forests. Nomenclature follows Integrated Taxonomic Information System (2018). Forest code prefixes indicate county (AD = Adams County, AL = Allen County, W = Wells County). For each forest, relative occurrence was categorized as R (rare [one or two occurrences]), O (occasional [sporadic occurrence]), F (frequent [widespread throughout]), and C (common [dominant in community]).

Species	AD01	AD02	AD03	AD04	AD05	AD06	AD07	AD08	AD09	AD10	AD11	AD12
Acer negundo L.					O							
Acer rubrum L.	C	R	C	R	R		R	C	F		R	O
Acer saccharinum L.				R	F	F				C		
Acer saccharum Marsh.	F	C	F	R	F	R		C	C			C
Aesculus glabra Willd.				R		F						
Carpinus caroliniana Walter			R	F	O	R	C		F			
Carya cordiformis (Wangenh.) K. Koch												
Carya ovata (Mill.) K. Koch					O							R
Celtis occidentalis L.												
Cephalanthus occidentalis L.												
Cornus racemosa Lam.					O							
Crataegus mollis (Torr. & A. Gray) Scheele	R				R				R			
Fagus grandifolia Ehrh.			F	C	F	F	C	R	F			R
Fraxinus americana L.	F		R		R				R			
Fraxinus pennsylvanica Marsh.					O			R				
Lindera benzoin (L.) Blume					O				R			
Liriodendron tulipifera L.					R							
Platanus occidentalis L.												
Populus deltoides W. Bartram ex Marshall	R											
Quercus bicolor Willd.					R							
Quercus rubra L.												
Robinia pseudoacacia L.					F		F					
Tilia americana L.					O	C						
Ulmus americana L.	R		F	R	O	C	F		R			
Ulmus rubra Muhl.	R				R					R		

Species	AD13	AD14	AD15	AD16	AD17	AL01	AL02	AL03	AL04	AL05	AL06	W01
Acer negundo L.				R								
Acer rubrum L.	F	C		F	F	C	C	C	R	R		R
Acer saccharinum L.												
Acer saccharum Marsh.	C	C	R	C	C	C	C	C	C	C		C
Aesculus glabra Willd.												
Carpinus caroliniana Walter				R		C		O	C	C		
Carya cordiformis (Wangenh.) K. Koch												
Carya ovata (Mill.) K. Koch					R	R						R
Celtis occidentalis L.						O		F				
Cephalanthus occidentalis L.										R		
Cornus racemosa Lam.												
Crataegus mollis (Torr. & A. Gray) Scheele										R	R	
Fagus grandifolia Ehrh.			R						R	C		
Fraxinus americana L.	F	F		R	R							
Fraxinus pennsylvanica Marsh.				R		O	R	O				
Lindera benzoin (L.) Blume												
Liriodendron tulipifera L.												
Platanus occidentalis L.												
Populus deltoides W. Bartram ex Marshall												
Quercus bicolor Willd.												
Quercus rubra L.												
Robinia pseudoacacia L.	R	R		R		F			R			
Tilia americana L.							C	R				
Ulmus americana L.	R	R		R	R	R	R	F		R		
Ulmus rubra Muhl.				R					R	R		

(*Continued next page*)

APPENDIX II. (*Continued*)

Species	W02	W03	W04	W05	W06	W07
Acer negundo L.						
Acer rubrum L.		R	O	C		
Acer saccharinum L.		F				
Acer saccharum Marsh.		R				
Aesculus glabra Willd.	O					
Carpinus caroliniana Walter						
Carya cordiformis (Wangenh.) K. Koch						
Carya ovata (Mill.) K. Koch				R		
Celtis occidentalis L.	R			R		
Cephalanthus occidentalis L.		F				
Cornus racemosa Lam.				F		
Crataegus mollis (Torr. & A. Gray) Scheele	C	R				
Fagus grandifolia Ehrh.				O		
Fraxinus americana L.			F	R	R	C
Fraxinus pennsylvanica Marsh.	C	R		R		
Lindera benzoin (L.) Blume		F	C		C	R
Liriodendron tulipifera L.						
Platanus occidentalis L.						C
Populus deltoides W. Bartram ex Marshall	R					
Quercus bicolor Willd.	R		R		R	
Quercus rubra L.	R					
Robinia pseudoacacia L.		C	C	F	C	R
Tilia americana L.						
Ulmus americana L.	C					
Ulmus rubra Muhl.				R		

APPENDIX III. List of overstory species encountered in studied forests. Nomenclature follows Integrated Taxonomic Information System (2018). Forest code prefixes indicate county (AD = Adams County, AL = Allen County, W = Wells County). For each forest, relative occurrence was categorized as R (rare [one or two occurrences]), O (occasional [sporadic occurrence]), F (frequent [widespread throughout]), and C (common [dominant in community]).

Species	AD01	AD02	AD03	AD04	AD05	AD06	AD07	AD08	AD09	AD10	AD11	AD12
Acer negundo L.				R	O							
Acer platanoides L.												
Acer rubrum L.	C	O	F	F	O	R	F	O	F			C
Acer saccharinum L.			O	O	F	R	R	O	O	C		
Acer saccharum Marsh.	O	C	F	C	C	O		O	C		C	C
Aesculus glabra Willd.				R								
Betula nigra L.				R	R					O		O
Carpinus caroliniana Walter	O				O	O	O	O	R			
Carya cordiformis (Wangenh.) K. Koch									O			R
Carya glabra (Mill.) Sweet												
Carya ovata (Mill.) K. Koch	O	F	R	R	O		F	F	O		O	O
Celtis occidentalis L.				R		F					O	
Cornus florida L.		R			R	O	R		R		F	R
Fagus grandifolia Ehrh.		O	F	O	O	O	O	F	F		R	F
Fraxinus americana L.	O							O				
Fraxinus pennsylvanica Marsh.					R							
Gleditsia triacanthos L.	R		R		R			R				
Juglans nigra L.					R					R	R	
Ostrya virginiana (Mill.) K. Koch	O	O	O		O	R	F	F	O		R	O
Platanus occidentalis L.												
Populus deltoides W. Bartram ex Marshall		O		R		C			O	O	R	
Populus tremuloides Michx.											R	
Quercus alba L.	R	O	R	R	O			O			O	R
Quercus bicolor Willd.					R							

(Continued next page)

APPENDIX III. (*Continued*)

Species	AD13	AD14	AD15	AD16	AD17	AL01	AL02	AL03	AL04	AL05	AL06	W01
Acer negundo L.												
Acer platanoides L.	O											
Acer rubrum L.	R	R	R	O	R	O	R	O	F			O
Acer saccharinum L.			O	O		O	R		R			
Acer saccharum Marsh.	C	C	C	C	C	O	C	C	F	C		C
Aesculus glabra Willd.												
Betula nigra L.											C	
Carpinus caroliniana Walter				R	R		R		O	O		
Carya cordiformis (Wangenh.) K. Koch						R	O					
Carya glabra (Mill.) Sweet		F										
Carya ovata (Mill.) K. Koch	O	O	O	O	O	C	F	R	O	O	C	O
Celtis occidentalis L.					R					F		
Cornus florida L.	R		R			R	R		O		R	O
Fagus grandifolia Ehrh.	O	R		F	R	O		O	F	O	R	
Fraxinus americana L.			R		R		R	O				
Fraxinus pennsylvanica Marsh.												
Gleditsia triacanthos L.	R											
Juglans nigra L.	R			O	F		R	R	R	R		
Ostrya virginiana (Mill.) K. Koch	O	C	F	O	O	F	R	R	O	R		O
Platanus occidentalis L.									R			
Populus deltoides W. Bartram ex Marshall	R			O	F	R			O	R		C
Populus tremuloides Michx.												
Quercus alba L.	O		R	R		O		R	R		R	
Quercus bicolor Willd.				R								

Species	W02	W03	W04	W05	W06	W0
Acer negundo L.						
Acer platanoides L.						
Acer rubrum L.		O		O	O	F
Acer saccharinum L.	O	F				R
Acer saccharum Marsh.	R	F	F	F	F	
Aesculus glabra Willd.	R			R		
Betula nigra L.	F					
Carpinus caroliniana Walter		R	R			F
Carya cordiformis (Wangenh.) K. Koch			F	O		R
Carya glabra (Mill.) Sweet						
Carya ovata (Mill.) K. Koch	O	O	R	F		
Celtis occidentalis L.		R		R		
Cornus florida L.	R	O		R	R	
Fagus grandifolia Ehrh.		O	O	R	C	R
Fraxinus americana L.		R				
Fraxinus pennsylvanica Marsh.					R	
Gleditsia triacanthos L.						R
Juglans nigra L.		R				
Ostrya virginiana (Mill.) K. Koch		O	F	C	O	R
Platanus occidentalis L.		R	O			
Populus deltoides W. Bartram ex Marshall	R		C		C	R
Populus tremuloides Michx.						
Quercus alba L.	O			R	R	
Quercus bicolor Willd.				R		

(*Continued next page*)

APPENDIX III. (*Continued*)

Species	AD01	AD02	AD03	AD04	AD05	AD06	AD07	AD08	AD09	AD10	AD11	AD12
Quercus macrocarpa Michx.					R							
Quercus rubra L.				F		R				R	R	R
Quercus velutina Lam.							O				R	
Robinia pseudoacacia L.								R				
Tilia americana L.	O		C	O	C	O				O	O	R
Ulmus americana L.	C	F	F	O	C	C	C	C	O	C	F	O
Ulmus rubra Muhl.	O	R	O	R			R	R		R	R	

Species	AD13	AD14	AD15	AD16	AD17	AL01	AL02	AL03	AL04	AL05	AL06	W01
Quercus macrocarpa Michx.												
Quercus rubra L.	O									R	R	
Quercus velutina Lam.			F				R	O		O		
Robinia pseudoacacia L.											F	
Tilia americana L.				O		O	F	F				
Ulmus americana L.	F	C	O	F	F	F	O	F	O	F	O	R
Ulmus rubra Muhl.				O		R			O			

Species	W01	W02	W03	W04	W05	W06	W07
Quercus macrocarpa Michx.							
Quercus rubra L.		O	R				
Quercus velutina Lam.		C	O				
Robinia pseudoacacia L.		R					
Tilia americana L.			C				R
Ulmus americana L.	R	F	O	O	F	R	C
Ulmus rubra Muhl.			R		R	R	

MAGNOLIA KOBUS: A STUDY OF THE POPULAR HORTICULTURAL SPECIES AND ITS RECENT INVASION OF NATIVE ECOSYSTEMS IN ONTARIO, CANADA

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ABSTRACT

Magnolia kobus DC., also known as Kobushi Magnolia, Northern Japanese Magnolia, or Kobus Magnolia, is a medium-sized deciduous tree native to the temperate forests of Japan. It is a popular choice in horticultural landscapes, due in part to its showy white flowers and attractive foliage. Some of the characteristics that make this species desirable for gardeners are the same features that have allowed for the development of its high invasive potential in native ecosystems. *Magnolia kobus* is very tolerant of a variety of climate and soil conditions, experiences little threat from disease and insect pests, and contains allelopathic compounds that can hinder the growth of surrounding native vegetation. As a result, once the plant becomes established in a manicured landscape or in natural areas, it can thrive relatively unhindered unless it is intentionally targeted for removal. This study researched the life history and invasive characteristics of *M. kobus* and the potential impacts of its invasion throughout the natural lands in the Royal Botanical Gardens in Hamilton, Ontario, Canada. Hypotheses for the recent establishment and spread of *M. kobus* were also developed and are discussed in this study. The population of *M. kobus* at Royal Botanical Gardens is the first documented occurrence of a naturalized population in Canada.

KEYWORDS: *Magnolia kobus*, invasive species, invasion lag time, species adaptability, climate change

INTRODUCTION

The Royal Botanical Gardens (RBG) in Hamilton and Burlington, Ontario, Canada contains over 900 hectares of protected natural lands that are at a high risk of invasive plant introductions due in part to their close proximity to horticultural collections. One example of an invasion by a non-native plant species is the spreading of *Magnolia kobus* DC. beyond the area in which individuals were planted. Several trees of *M. kobus* are located within the Magnolia Collection in the RBG Arboretum, the majority of which were planted in the 1960s and 1970s. In 2013, several thousand *M. kobus* seedlings were discovered throughout Hickory Valley, with the invasion radiating out from the edge of the Magnolia Collection into the adjacent forested ravines. As a result of intermittent removal efforts and the continual sprouting of new seedlings, a more specific quantification of seedlings was not feasible.

Magnolia kobus is recognized as an invasive species in the State of Delaware (McAvoy 2016), and naturalized populations have been observed in the southeastern Pennsylvania counties of Chester, Montgomery, and Bucks. In

2016, the first known record of a naturalized *Magnolia kobus* population in western Pennsylvania was reported in Butler County (Krayesky and Chmielewski 2016). The naturalization of this species is not yet recorded in authoritative sources, including the Invasive Plant Atlas of the United States (IPA 2018), Flora of North America North of Mexico (FNANM) (Flora of North America Editorial Committee 1993+), and Flora Ontario Integrated Botanical Information System (FOIBIS) (Newmaster and Ragupathy 2012), nor in the *Field Manual of Michigan Flora* (Voss and Reznicek 2012). The population of *M. kobus* at RBG is the first documented occurrence of a naturalized population in Canada.

This report examines the native range and habitat type of *Magnolia kobus*, its pollination ecology, and its invasive characteristics. The research provided insight for the development of hypotheses with respect to invasion and potential impacts of invasion, which are also discussed. The information is intended to be used as a reference for the development of a management strategy for *M. kobus* and to increase awareness of the high invasive potential of this species.

Study Species

Magnolia kobus is a medium-sized deciduous tree with 4 to 8 inch leaves that are simple, obovate, and abruptly acuminate. One of the key identifying features of this species is the presence of long hairs scattered along the sides of the veins and/or in the axils of the major lateral veins on the underside of the leaf (Figure 1) (Cullen et al. 2011). The buds on the tips of the twigs are covered with fine, silky hair. The twigs themselves have a strong sweet smell when broken. The white flowers are ca. 10 cm across and appear in the spring prior to leafing out (Gilman and Watson 1994). Young *M. kobus* trees do not flower, as this species takes about 15 years before it blooms for the first time (Randy Stewart Landscape Designs 2010).

The pink fruit is an aggregate of follicles called a follicetum (see Figure 2). The individual follicles usually contain one or two bright red seeds, and the total number of seeds contained within the follicetum ranges from 2 to 60. When the seeds are ripe, the follicles split open and the fleshy seeds are suspended on a thin string-like membrane called a funiculus (Barbour 2008).

Birds are attracted to the brightly coloured seeds of *Magnolia kobus*, the appeal of which is accentuated by the funiculus, which allows the seeds to dangle from the follicetum (Barbour 2008). Predation by mammals, such as mice and chipmunks, causes a reduction in seed survival. Since mammals are able to collect seeds that fall to the ground, it is advantageous for the plant to have the seeds eaten by birds while they remain on the tree (Stiles 1980). In this way, *M. kobus* has a means of ensuring the dispersal of its seeds.

Magnolias are dichogamous (Lloyd and Webb 1986), that is, the pistils and stamens mature at different times, and most *Magnolia* species, including *Magnolia kobus*, are protogynous (Sedgley and Griffin, 1989). When the flowers first open, the female organs are mature and receptive. After a brief period, the flowers close, and the female phase ends. The flowers reopen when the male organs are mature and able to shed pollen (Rose and Dosmann 2014).

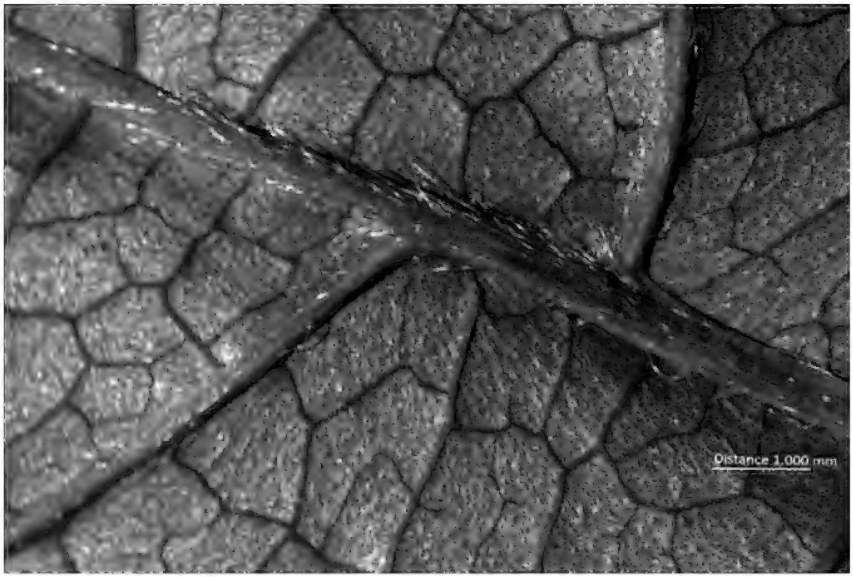

FIGURE 1. Underside of a leaf of *Magnolia kobus* showing long hairs along the edge of the veins and/or in the axils of the major lateral veins.

FIGURE 2. The fruit of *Magnolia kobus*, an aggregate of follicles called a follicetum. Each fruit contains 2–60 bright red seeds.

Magnolia species rely on beetles for pollination, and beetles in the family Nitidulidae are the main pollinators (Fulcher and White 2012). The flowers do not contain nectar, but instead secrete a fragrant sugary substance that attracts the insects. When beetles feed on newly-opened flowers in the spring, they land on the stigmas that are located in a central column above the stamens. As the insects crawl down into the flower in search of fresh pollen, any pollen grains from other flowers in the male phase that are attached to them are removed by the sticky stigmas (Essig 2015).

Magnolia kobus is native to temperate forests of Japan and is commonly found on all four of the main Japanese islands of Hokkaido, Honshu, Shikoku, and Kyushu. It grows in hills and piedmont regions (Ohwi 1965), which are defined as the areas at the base of mountains (National Geographic 2016). The species is tolerant of a variety of soil conditions, including clay, loam, and sand. It prefers well-drained soils that are slightly alkaline to acidic (Gilman and Watson 1994). Rich and moist forest soils with leaf litter are ideal for the germination of *Magnolia* species (United States Department of Agriculture 1948).

MATERIALS AND METHODS

Site Description

The "Magnolia West" collection of *Magnolia kobus* in the RBG arboretum, above Hickory Valley where this study was conducted, was established in 1970, although the species had been present elsewhere at RBG since at least 1958. Although RBG records for that period do not indicate when plants were moved from propagation or holding sites to their permanent locations, it is probable that about five flowering-size plants of *M. kobus* were planted at the site above Hickory Valley in 1970. A later addition, planted in 2014, was the cultivar *M. kobus* 'Edward A. Kehr.' *Magnolia* × *loebneri* Kache, a hybrid between *M. kobus* and *M. stellata* (Siebold and Zucc.) Maxim., is also represented in the collection, having been planted between 1970 and 1995. Cultivars include 'Merrill,' 'Leonard Messel,' and 'Ballerina' (J. Peter, personal communication; RBG plant records).

Several thousand small seedlings are located throughout Hickory Valley (Figures 3 and 4), but specific quantification was not feasible, as seedlings were removed by RBG staff throughout the duration of this study. As of 2015, the majority of the individuals of *Magnolia kobus* were 1 or 2-year old seedlings, but there were a few trees that were approximately ten years old. A larger individual that was cut down in Hickory Valley was in its 19th growing season. (Voucher specimen: Aug. 17, 2015, *Moesker s.n*; HAM, accession no. *59122*).

In 2014, several *Magnolia kobus* trees were girdled by RBG staff, since manual removal was not possible due to their large size. These efforts were conducted prior to the beginning of this study, and I observed the results of the girdling the following year. The results and consequential implications are discussed in this study.

Ecological Land Classification

Ecological Land Classification (ELC) is a system that delineates natural regions based on ecological factors including bedrock, climate, physiography, and vegetation (Government of Ontario 2019). RBG utilizes this system to classify habitat types within its natural area to identify rare habitats and potential locations of flora and fauna of interest. ELC has also been used to build upon RBG's inventory of plant species within the nature sanctuaries, and to create distribution maps of invasive non-native plants for the purpose of invasive species management. The result is a map of small polygons delineating ecologically distinct areas throughout the property. As of 2019, ELC is ongoing within RBG's nature sanctuaries.

The soil analysis portion of ELC is conducted by RBG staff and follows the protocol outlined in the *Field Manual for Describing Soils in Ontario* (Denholm and Schut 2009). This analysis includes

FIGURE 3. Seedlings of *Magnolia kobus*. Several thousand have been discovered throughout RBG's natural lands.

testing soil moisture, drainage, depth of mottles or gley, presence and depth of carbonates, and effective soil texture.

For this study, I analyzed the data associated with the ELC polygons in which *Magnolia kobus* was found, focusing on the vegetation list and the results of the soil analysis for each. I used this information to compare similarities between the species' native range and the environment in which the *M. kobus* seedlings were discovered. I also used the data to develop hypotheses for the invasive ability of this species.

Weed Risk Assessment System

Objective and reliable systems are required in order to better predict the invasive potential of a species prior to its introduction into an area (Pheloung et al. 1999). One such tool is the Weed Risk Assessment (WRA) system, developed by Dr. Paul Pheloung of the Western Australian Department of Agriculture (Australian Government Department of Agriculture 2015). This system evaluates species' properties such as climate requirements, naturalization in other regions, domestication history, and other ecological factors. Each property has an associated value, and the sum of the values associated with all the properties assessed provides a score that is used to assess the in-

FIGURE 4. Fast-growing seedlings of *Magnolia kobus* creating a dense wall near the edge of the natural area.

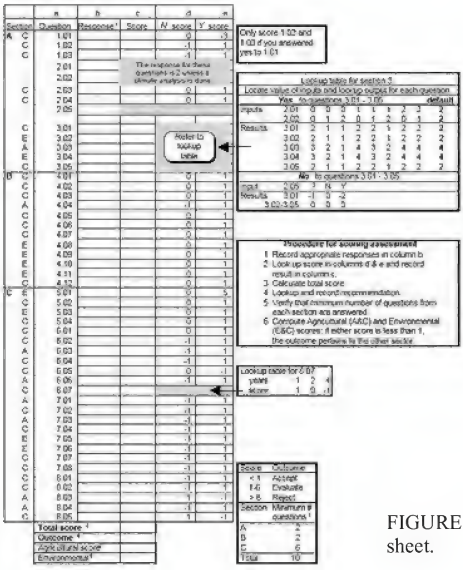

FIGURE 5. Sample Weed Risk Assessment scoring sheet.

vasive potential of a plant species, the impacts of an invasion, and the consequential acceptance or rejection of introduction (Koike and Kato 2006). A score of less than one indicates a low risk of invasion, and the plant may be accepted for introduction. A score of one to six poses a possible risk of invasion, and further evaluation is necessary. Finally, a score of six or greater suggests a high risk of invasion, and rejection of the species is recommended. The Weed Risk Assessment scoring sheet provides instructions for determining the score for each property, and is displayed in Figure 5. The first column of the scoring sheet consists of the letters A, E, and C, representing "agricultural", "environmental", and "combined", respectively. This refers to the type of ecosystem that is likely to be affected by the species assessed (Australian Government Department of Agriculture 2015). This latter aspect of the assessment was not related to the context of this study and is therefore not discussed further.

The WRA can be adapted for use in regions outside of Australia, as its accuracy in the identification of invasive plant species remains high beyond its country of origin (Gordon et al. 2008). When completing the risk assessment of *Magnolia kobus* for this study, the majority of the questions remained unaltered, but I modified three that pertain to the Australian climate in order to reflect the conditions that exist in Southern Ontario. Question 2.01 had originally read "Species suited to Australian climates" and was altered to "Species suited to Southern Ontario climates". Question 2.04 read "Native or naturalized in regions with extended dry periods" and was edited to read "Native or naturalized in regions with mean annual precipitation of 40–50 inches", referring to the mean annual precipitation in Hamilton, Ontario of 46.5 inches (The Weather Network, 2016). Finally, question 8.05 had read "Effective natural enemies present in Australia" and was changed to "Effective natural enemies present in Ontario".

INVASIVE CHARACTERISTICS

Lack of Predators

Magnolia species face few threats from pests and diseases. The plants contain compounds that have antimicrobial, nematicidal, and insecticidal properties (Fulcher and White 2012). *Magnolia kobus* contains several lignans, including kobusin and sesamin, whose biological activities protect the plant from insect pests (Kamikado et al. 1975; Trifunovi et al. 2003). The ability of this species to deter insect pests by chemical means increases its ability to overcome ecological barriers as it invades natural areas.

In its native range, *Magnolia kobus* is a host plant for *Caloptilia magnoliae* and *Gibbovalva kobusi*, both of which are moths in the family Gracillariidae (De Prins and De Prins 2019). It is also host to a variety of scale insects in the genera *Eulecanium*, *Pulvinaria*, and *Pseudaulacaspis* (García Morales et al. 2019). Magnolia scale (*Neolecanium cornuparvum*) is a pest that is managed within the Magnolia Collection at RBG, and some leaf miner damage has also been observed on the leaves of some of the *Magnolia* species, including *M. kobus*. However, these pests do not appear to pose a significant threat to the species.

The *Magnolia kobus* seedlings observed in the natural lands did not exhibit evidence of deer browse, despite the presence of a large local population of white-tailed deer. This suggests that these plants are not a preferred source of food for deer. The *M. kobus* seedlings are able to grow uninhibited, while many native tree and shrub species are continually stunted. This can result in the species having a competitive advantage over other plants that face pressures

from deer browsing, including witch hazel (*Hamamelis virginiana* L.) and dogwood species (*Cornus* spp.).

Hardy and Vigorous Grower

In 1894, about 30 years after *Magnolia kobus* was introduced to North America, it was described by American botanist Charles Sprague Sargent as being "the hardiest, most vigorous, and most rapid growing of all Magnolias" in New England (Sargent 1894). The average current year's growth of five *M. kobus* trees in Hickory Valley was 74.6 cm (29.37 in). These trees were approximately 10 years old, based on the number of tree rings counted in the cross-section of *Magnolia* trees that were of similar size. A plant that grows 12 inches or less per year is considered to be slow-growing, 12–24 inches per year is a medium growth rate, and above 25 inches per year is considered fast-growing (Arbor Day Foundation 2015). Based on these measurements, the rate of growth designates this species as fast-growing. The vigorous nature of *M. kobus* combined with the lack of growth control from deer browse and insect pests is likely to result in it overwhelming and outcompeting native plant species.

Magnolia kobus is more tolerant of cold weather than most species of *Magnolia* (Utah State University 2016). Its native range includes Hokkaido, the northernmost island of Japan where temperatures can reach –34.4°C (Davis Landscape Architecture 2016). The individuals in the Magnolia Collection at RBG are well within the hardiness range of the species. The property is located in North American Plant Hardiness Zone 6a, where the extreme minimum temperature is –23.3 °C. *Magnolia kobus* can tolerate conditions up to Zone 4, where –34.4°C is the extreme minimum temperature (Natural Resources Canada 2016; Brand 2015). Many of the other *Magnolia* species in the Collection are native to warmer southern latitudes and have lower cold tolerances.

Reproduction

The pollen from *Magnolia* species may be transported by beetles to a different plant, but insects often move between flowers on the same plant. In *Magnolia kobus*, this results in self-fertilization, as the species is self-compatible (Azuma et al. 2001). This provides an advantage when the species is established in new habitats. Self-fertilization permits the quick development of a population of individuals that have characteristics adapted to the new environment. This is also advantageous for an invading species as only one or a few individuals are required for the quick colonization of an area (Heiser 1962).

In addition to spreading by seed, *Magnolia kobus* is also able to reproduce by layering. This is a process by which a lower branch that is still connected to the main stem forms roots where it comes into contact with the soil (Evans and Blazich 1999) (Figure 6). Although the initial spread of a population may be limited by the presence of only a few mature seed-bearing trees, young seedlings are able to reproduce vegetatively. The ability of *Magnolia kobus* to

FIGURE 6. A branch of *Magnolia kobus* that is still connected to the main stem forming roots at the point where it came into contact with the soil.

reproduce both sexually and asexually increases its ability to quickly invade natural areas.

Allelopathy

Magnolia kobus plants contain sesquiterpene lactones, chemical compounds that can produce allelopathic effects on surrounding vegetation (Abdelgaleil and Hashinaga 2007). Two of these compounds that are found in *M. kobus* are costunolide and parthenolide (Park et al. 2010). In a study by Abdelgaleil and Hashinaga (2007), costunolide and parthenolide inhibited seed germination and root length of four test species, viz., wheat, lettuce, radish, and onion. The extent of germination inhibition was dependent upon the concentration of the chemicals added, but shoot growth of the test species was sig-

nificantly reduced at all levels of chemical concentration. A similar study by Abdelgaleil et al. (2009) using wild oats showed reductions in growth with increasing concentrations of costunolide and parthenolide. The presence of costunolide and parthenolide in *M. kobus* can result in allelopathic effects on nearby plant species by the release of the chemicals into the soil via roots and fallen debris (Hampton 2010).

HYPOTHESES EXPLANING THE INVASIVE ABILITY OF *MAGNOLIA KOBUS*

The invasion of non-native plants into natural areas following a lag phase often cannot be explained by a single factor. These events are frequently the result of a combination of stochastic and deterministic factors. Stochastic changes may provide increases in the availability of ideal site conditions that a species can take advantage of, while deterministic factors regarding the life history of a species can contribute to increases in invasive potential (Kowarik 1995). Three hypotheses for the recent establishment and spread of *Magnolia kobus* in RBG's natural lands were developed over the course of this study and are discussed below.

Similarities to Native Habitat

Magnolia kobus occurs throughout Japan, where it can be found in the mixed broadleaved–*Abies sachalinensis* forest, also called the Pan-Mixed forest. The typical vegetative composition of the mixed broadleaved–*Abies sachalinensis* forest consists of well-developed tree, shrub, and ground-cover layers. The canopy is dominated by *Abies sachalinensis* F.Schmidt, *Acer mono* Maxim., *Betula ermanii* Cham., *Quercus crispula* Blume., *Picea jezoensis* (Siebold & Zucc.) Carr., and *Tilia japonica* (Miq.) Simonk. *Magnolia kobus* exists below the canopy along with other smaller trees including *Acer palmatum* var. *matsumurae* (Koidz.) Makino, *Cornus controversa* Hemsl., *Kalopanax septemlobus* (Thunb. ex A.Murr.) Koidz, *Ostrya japonica* Sarg., and *Prunus sargentii* Rehder (Nakamura and Krestov 2005).

The majority of genera listed by Nakamura and Krestov (2005) as associates of *Magnolia kobus* in this forest type in its native range are located within RBG's natural lands. The associated genera found in the forest in which the seedlings are spreading include *Acer*, *Betula*, *Quercus*, *Tilia*, *Cornus*, *Ostrya*, and *Prunus*. This vegetative community type may therefore be indicative of an environment that is suitable for the growth and establishment of *M. kobus*.

Magnolia seeds germinate well in rich, moist soils with a layer of leaf litter in forested areas (United States Department of Agriculture 1948). According to the results of soil tests completed under Ontario's Ecological Land Classification (ELC) system at RBG, the average depth of organics was 3.09 cm in the polygons where *Magnolia kobus* was found, and the moisture regime of the soils ranged from Fresh to Moist. This supports my conclusion that the soil in the area

where the *M. kobus* seedlings were first discovered provides ideal conditions for seed germination.

Some invasive species retain the same habitat requirements over time, thereby limiting the range that they are able to occupy. The range of abiotic conditions that can be tolerated by a species depends on the amount of genetic diversity within the species and on the number and movement of propagules (Olyarnik et al. 2009). As noted above, *Magnolia kobus* grows in hills and piedmont regions in its native range (Ohwi 1965). According to William McAvoy, a botanist for the Delaware Department of Natural Resources and Environmental Control (personal communication), the invasive *M. kobus* is currently limited in Delaware to the piedmont regions in the northern part of the state. Based on the locations in which *M. kobus* naturalization has occurred, it appears that this species is not yet capable of adapting to a wide variety of habitat types. In RBG's natural lands, the species is spreading throughout ravines, which is consistent with its preferred habitat type. These ravines, in combination with the presence of associated vegetative community types and soil conditions, provide an ideal environment for the further establishment of *M. kobus*.

Ideal Climate Conditions

Abiotic factors, such as climatic conditions, are an ecosystem's first line of defense against invasions by limiting the establishment of non-native species to regions that provide conditions similar to those in their native range (Olyarnik et al. 2009). The establishment of *Magnolia kobus* at RBG may be attributed in part to changes in Hamilton's average spring temperatures, as described below.

The reproductive capacity of a plant depends on its ability to produce quality viable seed. This, in turn, depends on genetic, physiological, and ecological factors. The seed productivity of a plant generally depends on the viability of pollen. The main cause of reduced pollen viability may be low temperatures that occur during the time of flowering, which results in the inability of the pollen to fully mature (Kameneva and Koksheeva 2013). *Magnolia kobus* blooms in early spring when there is still potential for cold temperatures in southern Ontario. However, as a result of changes in climate conditions, the warmer weather has begun to arrive earlier in the year. Over the past several decades, the temperatures observed in Canada during the spring season have increased (Redmond and Abatzoglou 2014). The average spring temperature in Hamilton has increased 0.7°C since 1970, and the average temperature in the winter has increased 1.7°C within the same time period (Ontario Centre for Climate Impacts and Adaptation Resources 2011). This warming trend may allow for the maturity of *M. kobus* pollen, thereby increasing the probability of the development of viable seeds.

The average spring temperature and precipitation of a representative city on each of the main islands of Japan and, for comparison, of Hamilton, Ontario, are shown in Table 1. Hamilton's average temperature for the months of March and April is 2.95°C, well below that of three of the other Japanese cities. However, there is only a 0.2°C difference between the average spring temperatures

TABLE 1. Average spring temperature and precipitation of four representative Japanese cities and of Hamilton, Ontario. Data from Norwegian Meteorological Institute and Norwegian Broadcasting Corporation (2016) and Weatherbase (2016).

City	Average spring temperature (March & April) (°C)	Average spring precipitation (March & April) (mm)
Sapporo, Hokkaido, Japan	3.15	71.5
Tokyo, Honshu, Japan	11.30	110.0
Matsuyama, Shikoku, Japan	11.35	100.0
Nagasaki, Kyushu, Japan	12.65	155.0
Hamilton, Ontario	2.95	73.8

of Hamilton and Sapporo. The latter city is located in the northernmost range of *Magnolia kobus* in the northern Japanese island of Hokkaido. Thus, this species is evidently capable of producing mature pollen grains at temperatures of approximately 3°C. The warming trend in the city of Hamilton has brought its spring temperature to a level that is just within the tolerance range of *M. kobus*.

In order for *Magnolia* seeds to maintain their viability, they must remain moist (Barbour 2008). A lack of sufficient snowfall can result in the seeds drying out and losing their viability. Data collected from an Environment Canada weather station in Hamilton shows a decline in winter precipitation of 9 mm since the 1970s (Ontario Centre for Climate Impacts and Adaptation Resources 2011). However, the winters of 2013/14 and 2014/15 saw more total hours of snowfall than would be expected for the climatic average, and the temperatures remained below 0°C for most of the season (WeatherSpark 2016). The cold weather caused the majority of the snow to remain on the ground for the duration of each of those two winter seasons. The blanket of snow would have protected the seeds against winter desiccation until the spring thaw (Shimano and Masuzawa 1998).

Disturbance and Adaptability

Shelford's Law of Tolerance states that the distribution of a species is controlled by the environmental factor that the species can tolerate the least. Environmental factors that can limit plant species development include temperature, soil pH, and moisture. Three steps must be taken in order to determine whether or not a factor will limit the range of a species. First, the stage of the plant life cycle that is most sensitive to the factor must be determined. Second, the level of tolerance of that stage must be determined. Finally, it must be shown that the variations of the factor are within the species' tolerance limits in its native range and that they are beyond the limits outside of its range (Krebs 2008).

Magnolia kobus requires gaps in the forest canopy for regeneration (Nakamura and Krestov 2005), which indicates that light availability is a growth-limiting factor for this species. Disturbance may also directly influence the success of an invasive species by altering the suitability of the environment, or

indirectly by increasing the availability of resources through the reduction of competing species. The mortality and canopy dieback of ash trees (*Fraxinus* spp.) due to the invasive emerald ash borer (EAB) has created gaps in the canopy of RBG's forests. These canopy gaps provide an opportunity for *M. kobus* to become established as the availability of light increases. All of the ELC polygons that contained *M. kobus* included ash species. Dieback of ash species due to EAB was first acted upon at RBG in 2012 by pruning and by the removal of hazard trees. Biennial insecticidal injections of healthy ash trees (where 90% or more of the canopy remains intact) also began in 2012 (d'Entremont and Burtenshaw 2013). As of 2016 these management actions were ongoing, and the peak loss of ash trees occurred between 2014 and 2015 (Theysmeyer 2016).

Although light is becoming increasingly available in the forest, much of the forest floor, where the *M. kobus* seedlings are located, is in full shade. The successful establishment of the large number of *M. kobus* seedlings may be attributed to the ability of the species to adjust its phenotype, or that of its offspring, in response to environmental conditions. This ability is known as phenotypic plasticity (Sultan 2000). Invasive species generally exhibit significantly higher phenotypic plasticity than non-invasive species (Davidson et al. 2011). Phenotypic plasticity results in the adaptability of a species to different environments if the genotype maintains fitness in poor environmental conditions or increases fitness in ideal conditions, thereby permitting the species to be successful in a variety of environments. By altering its phenotype, *M. kobus* would be capable of overcoming abiotic barriers (such as light availability) that protect an ecosystem against invasion by non-native species. The reallocation of resources to growth and reproduction in *Magnolia kobus* is also likely as a result of a lack of predators, as the plants are no longer required to use resources for defense purposes. For example, a plant can increase the allocation of nitrogen to photosynthesis and reduce allocation to the development of defense structures (Gioria and Osborne 2014). This would allow *M. kobus* plants to allot energy towards adapting to the new environment, resulting in successful establishment.

THREAT AND IMPACTS

Results of the Weed Risk Assessment System

According to the Weed Risk Assessment scoring system, a score that is greater than six suggests that the species being assessed poses a high invasive potential, and rejection of its introduction is recommended. Following the completion of the WRA for *Magnolia kobus*, the species obtained a score of 11. According to this assessment, *M. kobus* poses a high risk of invasion, and rejection of future introductions of the species into the gardens at RBG is recommended. The complete assessment results can be viewed in detail in Table 2.

TABLE 2. Results of the Weed Risk Assessment for *Magnolia kobus*. The columns, from left to right, are: (i) the category of the criterion, where A = agricultural, E = environmental, and C = combined; (ii) the subject area of the criteria; (iii) the number of the criterion; (iv) statement of the criterion; (v) response; and (vi) score. The total score is 11, which indicates the species exhibits a high risk of invasion and is to be rejected.

			History/Biogeography		
A	*Domestication/ cultivation*	1.01	Is the species highly domesticated? If answer is 'no' go to question 2.01	Y	–3
C		1.02	Has the species become naturalized where grown?	Y	1
C		1.03	Does the species have weedy races?	?	
	Climate and distribution	2.01	Species suited to Southern Ontario climates (0-low; 1-intermediate; 2-high)	2	2
		2.02	Quality of climate match data (0-low; 1-intermediate; 2-high)	2	2
C		2.03	Broad climate suitability (environmental versatility)	Y	1
C		2.04	Native or naturalized in regions with mean annual precipitation of 40–50 inches	Y	1
		2.05	Does the species have a history of repeated introductions outside its natural range?	Y	
C	*Weed*	3.01	Naturalized beyond native range	Y	2
E	*elsewhere*	3.02	Garden/amenity/disturbance weed	N	0
A		3.03	Weed of agriculture/horticulture/forestry	N	0
E		3.04	Environmental weed	Y	2
		3.05	Congeneric weed	?	
			Biology/Ecology		
A	*Undesirable*	4.01	Produces spines, thorns or burrs	N	0
C	*traits*	4.02	Allelopathic	Y	1
C		4.03	Parasitic	N	0
A		4.04	Unpalatable to grazing animals	Y	1
C		4.05	Toxic to animals	N	0
C		4.06	Host for recognized pests and pathogens	N	0
C		4.07	Causes allergies or is otherwise toxic to humans	N	0
E		4.08	Creates a fire hazard in natural ecosystems	N	0
E		4.09	Is a shade tolerant plant at some stage of its life cycle	Y	1
E		4.10	Grows on infertile soils	N	0
E		4.11	Climbing or smothering growth habit	N	0
E		4.12	Forms dense thickets	N	0
E	*Plant type*	5.01	Aquatic	N	0
C		5.02	Grass	N	0
E		5.03	Nitrogen fixing woody plant	N	0
C		5.04	Geophyte	N	0
C	*Reproduction*	6.01	Evidence of substantial reproductive failure in native habitat	N	0
C		6.02	Produces viable seed	Y	1
C		6.03	Hybridizes naturally	?	
C		6.04	Self-fertilization	Y	1
C		6.05	Requires specialist pollinators	Y	–1
C		6.06	Reproduction by vegetative propagation	Y	1
C		6.07	Minimum generative time (years)	>4	–1
A	*Dispersal*	7.01	Propagules likely to be dispersed unintentionally	N	–1
C	*mechanisms*	7.02	Propagules dispersed intentionally by people	Y	1
A		7.03	Propagules likely to disperse as a produce contaminant	N	–1
C		7.04	Propagules adapted to wind dispersal	N	–1
E		7.05	Propagules buoyant	N	–1
E		7.06	Propagules bird dispersed	Y	1
C		7.07	Propagules dispersed by other animals (externally)	N	–1
C		7.08	Propagules dispersed by other animals (internally)	N	–1
C	*Persistence*	8.01	Prolific seed production	Y	1
A	*attributes*	8.02	Evidence that a persistent propagule bank is formed (>1 yr)	?	
A		8.03	Well controlled by herbicides	?	
C		8.04	Tolerates or benefits from mutilation, cultivation or fire	Y	1
E		8.05	Effective natural enemies present in Ontario	N	1

Threats to Native Vegetation

The leaves of *Magnolia kobus* remain green until late autumn, well after the leaves of native plants have changed colour or have dropped. This gives *M. kobus* the ability to produce and store more energy than native plant species (Wenning 2014). This factor, in addition to the species' lack of predators, vigorous growth habit, allelopathic properties, ability to reproduce vegetatively, and tolerance of a variety of light conditions, contributes to the competitive advantage held by *M. kobus*. Such an advantage threatens the growth of other less competitive species, thereby threatening to alter the structure of a vegetative community.

American robins in the Magnolia Collection at RBG were observed in October 2015 consuming several seeds at a time before flying into the adjacent forest. The birds returned within a few minutes to continue feasting on the bright red fruit before again retreating into the forest. This pattern continued until the *Magnolia* trees were stripped of their fruit. Native fruiting species such as gray dogwood (*Cornus racemosa* Lam.) are used as a food source by birds in the fall months when *Magnolia* seeds are also available (United States Department of Agriculture 2002). Since birds are drawn to the large and attractive *Magnolia* seeds, they consume smaller amounts of the fruit of native species, thereby contributing to the dispersal of *M. kobus* while limiting the spread of native species.

Seed Nutritional Value

Although the ecological threats posed by *Magnolia kobus* are significant, its presence also has the potential to benefit migratory bird species. The seed coat (testa) of many *Magnolia* species consists of five layers, including a pellicle, hypodermis, fleshy tissue, inner hypodermis, and a woody inner testa. The middle fleshy layer contains oil and reducing sugars (Barbour 2008). The reducing sugars include glucose, fructose, and galactose, which are the main forms of carbohydrates used by birds for energy (Black 2015). *Magnolia* species produce fruit with a high fat content that ranges from 33–62% (Frick-Ruppert 2010). Fat is more useful for migrating birds than sugar or protein, since one gram of fat has nine calories, while the same amount of sugar or protein has only four calories (United States Department of Agriculture 2016). The fat in the seeds of *M. kobus* can provide migratory birds with the energy that they need to reach their destination.

RECOMMENDED FUTURE STEPS

Due to the competitive nature of *Magnolia kobus* and its ability to quickly spread throughout forested ravines, immediate removal of the plants in RBG's natural lands was recommended. Areas where the species is abundant should not necessarily be labelled as being top priority. An area may contain many young seedlings, but another may have older individuals that are producing fruit. The

removal of *M. kobus* plants that are flowering and producing seed should be a high priority. Currently, the majority of the *M. kobus* plants in the RBG natural lands are young seedlings. Although it will be a number of years before they produce flowers and seeds, the seedlings are capable of reproducing vegetatively. It was therefore recommended that the young plants be removed as soon as possible.

The high score for *Magnolia kobus* in the Weed Risk Assessment indicates that it should not be planted in the gardens at RBG in the future. This result indicates a high risk of invasion based on several of the species' characteristics, which further supports the recommendation for its immediate removal from the gardens at RBG, as the seeds will continue to disperse, and the plants will continue to adapt to the local environmental conditions. Failure to remove the source of the problem will serve to exacerbate the ecological risks associated with this *Magnolia* species, and the offspring may develop characteristics that enable them to invade a variety of habitats.

Based on observations of *Magnolia kobus* trees that had been girdled the previous year by RBG staff, this method is not the most effective means of controlling the spread of the species. Some dieback was observed on the trees that had been girdled, but the wounds ultimately stimulated growth via shoots from the root collars. Since the plants are also able to reproduce vegetatively, girdling of the main stem may result in shoots sprouting from the root system. The most effective control method for *M. kobus* is physical removal of the entire plant, including the roots. Young seedlings can easily be hand-pulled, and trees with a diameter at breast height of up to approximately 5 cm can be removed with a shovel or tree extraction tool. Larger trees can be cut down and the stump treated with an herbicide containing glyphosate (Reynolds 2016).

As previously discussed, many native fruiting species are utilized as a food source by birds in the autumn months when the *Magnolia* seeds are also mature (United States Department of Agriculture 2002). Since birds are drawn to the large and attractive *Magnolia* seeds, they consume less fruit of native species, thereby contributing to the dispersal of *Magnolia kobus* while limiting the spread of native species. Future restoration projects in or near areas where *M. kobus* is found should include native species that produce fruit at a time that coincides with the appearance of the fruit of *M. kobus*. The fruit of the native species should also be visually attractive (e.g., brightly coloured) and have a high fat content and high antioxidant concentrations. Fat provides energy for both migratory and non-migratory birds, and high levels of antioxidants protects the birds against oxidative damage. This damage can result from fasting during long-distance flight and from free radicals that are produced during fat metabolism (Bolser et al. 2013). Native species that produce fruit with the desired characteristics should be planted as part of restoration projects in order to compete with *M. kobus* as a food source for birds. Species selection for restoration projects is site-specific, and the plants that are selected for planting should reflect the species composition of the surrounding area or of a reference ecosystem to which the area is being restored. A list of native species suitable for restoration plantings at RBG is presented in Table 3. According to RBG's checklist of spon-

TABLE 3. Native species that produce nutritious fruit at a time that coincides with *M. kobus* fruit production in autumn and that are appropriate for restoration plantings at RBG.

Scientific Name (Common Name)	Beneficial Fruit Characteristics	Additional Information
Viburnum recognitum (Southern Arrow-wood)	Very high in antioxidants	*Viburnum dentatum* is described by many sources as being highly favoured by birds due to its very high fat and antioxidant content. Others simply list "Arrow-wood" as being a provider of these benefits. *Viburnum. recognitum* is the species located within CPNS.
Cornus racemosa (Gray Dogwood)	High fat content	
Cornus sericea (Red Osier Dogwood)	High fat content	
Cornus alternifolia (Alternate-leaved Dogwood)	High fat content	Information could not be found regarding the nutritional content of this particular species. However, the fruit of *Cornus* spp. are generally high in fat, with the exception of *C. amomum* (Silky dogwood).
Lindera benzoin (Spicebush)	High fat and protein content	Since this is a dioecious species, both male and female plants should be present in a restoration.
Sambucus Canadensis (American Elderberry)	Rich in carbohydrates and protein, high in antioxidants	
Prunus virginiana (Choke Cherry)	High fat content	

taneous flora (Smith 2010), these species occur naturally in RBG's Cootes Paradise Nature Sanctuary.

CONCLUSIONS

Abiotic factors, such as climatic conditions, are an ecosystem's first line of defense against invasions (Olyarnik et al. 2009). Since *Magnolia kobus* is tolerant of a wide range of temperatures, soils, and light availability, the plants are likely to overcome the abiotic barrier to invasion once germination has occurred. Once the seeds germinate, the plants will have overcome the greatest barrier to establishment, as climate conditions may have successfully hindered seed germination until recent years.

Magnolia kobus is a popular choice for horticultural landscapes because of its year-round attractiveness and its ability to tolerate a variety of environmental conditions. This has allowed the species to become established in regions

well beyond its native range, and it is now beginning to display characteristics that suggest a high invasive potential. Due to its popularity in manicured landscapes, the risk of further invasion continues to increase. Public education is critical for enhancing awareness of the ecological threats posed by this *Magnolia* species. Preventive actions are especially important in these early stages of its invasion, and avoiding the planting of *M. kobus* will help to protect the biodiversity that would be threatened by its establishment in native ecosystems.

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OBSERVATIONS ON INVASIVE PLANT PROPAGULES WASHED FROM FORESTRY VEHICLES AND BEST MANAGEMENT PRACTICES

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ABSTRACT

Vehicles and mobile equipment are recognized pathways for the spread of invasive plants in forests; yet washing them is not in common use today, despite its being a cost-effective preventive tactic. We report on the operational practice of washing, the development of best management practices, and observations on intercepted plant species in the managed forests of the Menominee Indian Tribe of Wisconsin. A commercially available vehicle undercarriage wash system was used to wash street-legal vehicles, and pressure washers were used to wash mobile equipment. The soil washed from street-legal vehicles was collected and placed in raised beds and left for one year to permit the seeds to germinate and emerge for identification. A total of 48 species of plants from 18 families were intercepted via vehicle washing, 42% were non-native plants and 11% were invasive plants. Best management practices were developed for several user groups with the goal of minimizing the unintentional spread of invasive plants.

KEYWORDS: Invasive species, prevention, vehicle washing, human-mediated dispersal, weed seed spread, propagule pressure

INTRODUCTION

Vehicles, mobile equipment, and even footwear are recognized pathways for the invasion of environmentally detrimental invasive plants in terrestrial ecosystems (Ware et al. 2012, Bajwa et al. 2018, Rew et al. 2018). In managed forests, for example, accidental introduction of such plants and their spread by humans is undoubtedly due to vehicles, mobile equipment, and materials accompanying recreational users, foresters, wildland firefighters, road crews, logging operations, site preparation, and planting activities. Preventive washing of vehicles and mobile equipment that travel to forests is a well-intentioned integrated weed management tactic, but this is expensive, logistically challenging, and difficult to enforce, and consequently is not in common use in the United States other than during fire management by the USDA-Forest Service, (Trent et. al. 2002, Fleming 2008) and the US military (Rew et al. 2018).

On the Menominee Indian Reservation in northeastern Wisconsin, which con-

sists of 235,560 acres, 87% of the land is under sustained yield forest management, and this long-term stewardship has enabled the land to remain an unfragmented remnant of the prehistoric Lake States forest. The 2,573 miles of unimproved dirt roads distributed throughout the reservation, most of which were built between 1930 and 1950, are open only to enrolled tribal citizens, Menominee Tribal Enterprises (MTE) forestry and road crew vehicles, 25 logging businesses, various Tribal departments, and invited visitors. Unfortunately, these roads also are a pathway for invasive plants. However, despite over 160 years of forest management, the reservation is relatively uninvaded compared to the other areas of the upper Midwest and eastern US (Oswalt et al. 2015), largely due to minimal development and other changes in land use. Furthermore, of the 112 terrestrial invasive plant species that are regulated by the State of Wisconsin (Wisconsin Administrative Code 2017), only 28 are known to exist within the reservation. Due to the increasing abundance in the region of invasive plants that threaten the reservation, it became a priority for MTE to prevent further introductions and spread from vehicles to protect the ecological integrity of this nationally renowned forest.

MTE, which is the forestry and lumber mill business section of the Tribe, began in 2016 to develop best management practices for the washing of all forestry related vehicles and mobile equipment as a component of their integrated weed management program. To accomplish this for mobile equipment, pressure washers were purchased to clean ATVs, UTVs, road graders, backhoes, dozers, roller choppers, anchor chains, a Bracke planter, forwarders, skidders, drags, and processors. A pressure washer is permanently installed at the MTE Forestry Center offices in Keshena, Wisconsin, and a mobile pressure washer is mounted on a water tender truck. For street-legal vehicles (SUVs, light-duty trucks, wildfire engines, gravel trucks, log trucks, and trailers) a commercially available wheel and undercarriage wash was permanently installed at the lumber mill in Neopit, Wisconsin. At peak activity, over 70 log trucks and other vehicles enter the mill yard each day hauling logs and on other business.

To make progress towards the goal of minimizing the spread of invasive plants, our objectives were to establish a washing program, develop best management practices, and observe what plants are being spread. There is a need to assess if this washing program is logistically feasible at an operational scale in forest management, and to justify the effort by observing which species of plants are being unintentionally spread.

MATERIALS AND METHODS

To wash mobile equipment (e.g., logging equipment), a SC30008DAF diesel pressure washer on a mobile skid, manufactured by Hydro Tek Systems Inc. of Redlands, California, was mounted on a 1993 Ford L8000 water tender with a 1000-gallon tank (Figure 1). Key to the efficient performance of this system is its ability to be operated by one person (although there are two spray wands that could be used), its ability to reach high pressures, and its hot water capabilities (up to 200° F) that can be used if needed to remove tough deposits.

To wash street-legal vehicles, a Moby Dick Quick 732 wash unit (Frutiger Company AG, Winterthur Switzerland) was opened on August 23, 2016 at the MTE lumber mill for use by authorized drivers. Key to the performance of such a system is automated operation for the drivers to pass

FIGURE 1. A pressure washer mounted on a 1000-gallon water tender is used to clean a forwarder before transport to the next cutting unit to prevent the spread of invasive plants.

through, water recycling, and a system to collect debris removed from the rinse water. The wash platform is 9.5 ft wide and 24.0 ft long allowing for two full rotations of log truck tires over a ramp with integrated water nozzles (Figure 2). The weight limit is 33,069 lbs/axle. Water is pumped from a 10,000-gallon supply tank and is sprayed on the sides and undersides of the vehicles under low pressure and high volume to dislodge soil deposits, organic matter, and plant propagules that have accu-

FIGURE 2. An automated wash system is used to clean the wheels, wheel wells, bumpers, and undercarriage of pick-ups, SUVs, log trucks and trailers, wildfire engines, and gravel trucks to prevent the spread of invasive plants. The wash platform is 24 feet long, allowing for two full rotations of tractor trailer tires over a ramp and side-bars with integrated water nozzles.

FIGURE 3. Raised beds were used to grow plants from the soil deposits, organic matter, and plant propagules washed from 846 vehicles in an automated wash system from September through mid-November 2016.

mulated on the wheels, wheel wells, bumpers, and undercarriage. Rinse water flows back to the tank, where alum flocculent assists in the settling of the fine particles to the bottom of the tank. Three coarse filters made of sheet metal were added to the tanks to keep bark out of the pumps. A scraper conveyor removes the debris from the bottom of the tank and deposits it in a wet particulate matter collection bin for burial at a landfill. For detailed washing of light-duty trucks, SUVs, ATVs and UTVs, wildfire engines, and miscellaneous forestry equipment at the Forestry Center, a pressure washer (model 2SF22ESI.AHE), manufactured by Cat Pumps of Blaine, Minnesota, is available for use.

Instead of disposing it in a landfill, from September through mid-November the soil from the automated wash system was placed into outdoor raised beds (Figure 3). During this time period, the washer's event recorder indicates that it had washed 846 vehicles. The raised beds were unshaded and had approximately 8 inches of soil spread out over 344 square feet. After overwintering, the seeds in the soil germinated and plants emerged during the summer 2017 growing season. In August 2017 plants were collected, identified, and categorized as native, non-native, or invasive species. Invasive plants are defined as non-native species that cause ecological or economic harm, or harm human health. Voucher specimens were deposited in the Freckmann Herbarium at the University of Wisconsin-Stevens Point (UWSP).

RESULTS AND DISCUSSION

A total of 48 species of plants (five of which were identified only to genus) from 18 families were washed from the vehicles and identified in the beds (Table 1). Three of the five plants identified to genus only were in genera that have both native and non-native species in Wisconsin; accordingly, their status could not be determined. Of the remaining 45 species, 21 were native plants (representing 47% of the total), 19 were non-native plants (42%), and five were invasive plants

TABLE 1. Native, non-native, and invasive plants that emerged from soil deposits, organic matter, and plant propagules cleaned from vehicles in an automated wash system.

Taxon	Family	Common name	Status	Life-form	Seed type
Acer rubrum L.	Sapindaceae	red maple	native	tree	samara
Achillea millefolium L.	Asteraceae	yarrow	native	forb	cypsela
Agrostis gigantea Roth	Poaceae	redtop	non-native	graminoid	caryopsis
Ambrosia artemisiifolia L.	Asteraceae	rag-weed	native	forb	cypsela
Arctium minus Bernh.	Asteraceae	burdock	invasive	forb	cypsela
Bidens frondosa L.	Asteraceae	common beggar-ticks	native	forb	cypsela
Carex sp.	Cyperaceae	sedges	unknown	graminoid	achene
Cerastium fontanum Baumg.	Caryophyllaceae	mouse-ear chickweed	non-native	forb	capsule
Chenopodium album L.	Amaranthaceae	lambs quarters	non-native	forb	achene
Digitaria cognata Schuly.) Pilg.	Poaceae	fall witch grass	native	graminoid	caryopsis
Digitaria ishaemum (Schreb.) Muhl.	Poaceae	smooth crabgrass	non-native	graminoid	caryopsis
Digitaria sanguinalis (L.) Scop.	Poaceae	hairy crab grass	non-native	graminoid	caryopsis
Echinochloa muricata (P. Beauv.) Fernald	Poaceae	barnyard grass	native	graminoid	caryopsis
Eragrostis pectinacea (Michx.) Nees	Poaceae	tufted love grass	native	graminoid	caryopsis
Erigeron strigosus Wild.	Asteraceae	daisy fleabane	native	forb	cypsela
Euphorbia maculata L.	Euphorbiaceae	spotted sandmat	native	forb	capsule
Fallopia scandens (L.) Holub	Polygonaceae	black bindweed	native	forb	achene
Fragaria vesca L.	Rosaceae	woodland strawberry	native	forb	achene
Galeopsis tetrahit L.	Lamiaceae	hemp nettle	invasive	forb	nutlet
Galinsoga quadriradiata Ruiz & Pav.	Asteraceae	quickweed	non-native	forb	cypsela
Gypsophila muralis L.	Caryophyllaceae	baby's breath	invasive	forb	capsule
Lepidium densiflorum Schrad.	Brassicaceae	peppergrass	non-native	forb	silicle
Leucanthemum vulgare Lam.	Asteraceae	common daisy	non-native	forb	cypsela
Matricaria discoidea DC.	Asteraceae	pineapple-weed	non-native	forb	cypsela
Medicago lupulina L.	Fabaceae	black medick	non-native	forb	nutlet like legume
Melilotus sp.	Fabaceae	sweet clover	invasive	forb	nutlet like legume

Mollugo verticillata L.	Molluginaceae	carpet weed	non-native	forb	capsule
Odontites vulgaris (Bellardi) Dumort.	Orobanchaceae	red bartsia	non-native	forb	capsule
Oxalis stricta L.	Oxalidaceae	yellow wood sorrel	native	forb	capsule
Panicum capillare L.	Poaceae	common witch grass	native	graminoid	caryopsis
Panicum dichotomiflorum Michx.	Poaceae	fall panic grass	native	graminoid	caryopsis
Persicaria maculosa Gray	Polygonaceae	spotted lady's-thumb	non-native	forb	achene
Persicaria punctata (Elliott) Small	Polygonaceae	smartweed	native	forb	achene
Phleum pratense L.	Poaceae	timothy	non-native	graminoid	caryopsis
Plantago rugelii Decne.	Plantaginaceae	red-stalked plantain	native	forb	capsule
Poa palustris L.	Poaceae	marsh blue grass	native	graminoid	caryopsis
Polygonum achoreum S.F. Blake	Polygonaceae	leathery knotweed	native	forb	achene
Polygonum ramosissimum Michx.	Polygonaceae	bushy knotweed	native	forb	achene
Setaria pumila (Poir.) Roem. & Schult.	Poaceae	yellow foxtail	non-native	graminoid	caryopsis
Silene latifolia Poir.	Caryophyllaceae	white-cockle	non-native	forb	capsule
Solidago sp.	Asteraceae	goldenrod	unknown	forb	cypsela
Trifolium arvense L.	Fabaceae	rabbitfoot clover	non-native	forb	nutlet like legume
Trifolium pretense L.	Fabaceae	red clover	non-native	forb	nutlet like legume
Trifolium repens L.	Fabaceae	white clover	invasive	forb	nutlet like legume
Verbascum sp.	Scrophulariaceae	mullein	non-native	forb	capsule
Verbena bracteata Lag. & Rodr.	Verbenaceae	prostrate vervain	native	forb	nutlet
Verbena urticifolia L.	Verbenaceae	white vervain	native	forb	nutlet
Vicia sp.	Fabaceae	vetch	unknown	forb	legume

(11%). The non-native plants are common weeds that cause little damage; however the invasive species are of ecological concern by outcompeting native species. For example, *Galeopsis tetrahit* L. (hemp nettle) is a legally restricted species in the State of Wisconsin, although it was already known to exist on the reservation. We expected that the most troublesome invasive forb spread by humans on the reservation, *Alliaria petiolata* (M. Bieb.) Cavara & Grande (garlic mustard), would be observed but it was not. Perhaps, it will emerge from the seed bank as monitoring continues in the future.

The dominant plant life-forms were forbs (73%) and graminoids (25%), although one tree (2%) was observed (Table 1). The seed types picked up by vehicles were diverse and were typically small seeds. Because the raised beds were outdoors, there is a possibility that some wind-dispersed seed germinated in the plots or grew through the mud from the gravel below. We would recommend a soil weed barrier and screening to prevent these potential sources in future studies, or use of a greenhouse.

Invasive plants are increasingly causing negative impacts to native ecosystems and confounding forest management activities (Liebhold et al. 2017). Because stronger preventive tactics are needed, best management practices related to vehicle and mobile equipment washing for MTE have been developed (Table 2) based on the assumption that washing is the most cost-effective method of invasive plant management. Results from these operational trials indicate that this activity is a worthwhile effort which is not financially or logistically impossible to implement. A few minutes of preventive action can protect the forest for generations to come. Feedback from log truck drivers indicated that they appreciate that the washing is fast and that they don't have to exit their truck. They like to use the wash to keep their trucks clean for highway patrol inspections, maintenance, and pride. Some truckers thought the width of the unit is too narrow, but this was not a concern for all drivers.

Challenges for the future include the re-routing of log trucks in the mill yard to make passes through the wash more convenient for the drivers and a compliance system to increase usage. Furthermore, the amount of species being introduced and spread is likely much larger than that described here, as other pathways of species introduction exist, such as animals, birds, wind, footwear, clothing, mower decks, and scientific equipment. Of particular concern is privately owned cars and light-duty trucks, and it would be desirable to install a smaller undercarriage wash in a non-industrial location in the future. The use of preventive washing is an option for land managers to implement and ideally integrated into holistic biosecurity plans incorporating the prevention of introductions of invasive plants as well as insects, pathogens, and other organisms.

ACKNOWLEDGMENTS

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TABLE 2. Best management practices for vehicle and equipment washing developed for Menominee Tribal Enterprises to prevent the invasion and spread of invasive plants. Washing is not required during the low-risk period between freeze-up and break-up.

Street-legal Vehicles (automated truck wash)

Required washing

- All *log trucks* driven on off-reservation logging jobs *before* driving on reservation forest roads
- Vehicles driven from off-reservation by official *MTE visitors*, such as government agency employees, research scientists, inventory crews, and tour participants if their vehicles will be going on main haul roads or logging roads
- Pre-planned *fire equipment* brought in to assist with fires, prescribed and initial attack, before driving on forest roads. In addition, these vehicles can be manually pressure washed at the Forestry Center, if needed (They should be cleaned at their stations or en route)
- MTE *fire vehicles* when returning from off-reservation details if they are not cleaned en route
- Forestry, Fire Management, and Roads Dept. *trucks and SUVs* whenever passing by the mill, when muddy, or after having worked in or near a garlic mustard infestation. This should not totally replace occasional detailed pressure washing
- MTE *lumber delivery trucks* when returning from off-reservation if they went off pavement

Voluntary washing

- All *tractor trailers* after unloading each load of logs or bolts at the mill from on-reservation log jobs (bark should be swept from trailers before washing)
- Tractor trailers hauling pulp loads to off-reservation mills do not need to go to the MTE mill for washing if it's out of their way
- Tractor trailers being used to buy logs from the MTE millyard
- Initial attack resources called in to assist on a going fire (They should be cleaned at their stations or en route)

Off-road Machinery (pressure washing)

Required washing (Equipment owned by MTE departments or contractors)

- Loggers—Processors, skidders, forwarders, drags
- MTE Forest Development—Grapple skidder, anchor chain, roller choppers, Bracke planter
- MTE Fire Management[1]—Engines, skid steers, UTVs, bulldozers, trailers
- MTE Roads Dept.[2]—Bulldozers, front end loaders, graders
- MTE Forestry Depts.— Trucks, SUVs, UTVs, ATVs, trailers

Washing policy

- Any equipment that is *brought onto the reservation* must be thoroughly power washed and free of all plant material and soil or entry will be denied upon inspection
- Any equipment that is moving (e.g., walking or via trailer) from *one compartment to another compartment within the reservation* must be thoroughly power washed and free of most plant material and soil
    a. The operators of the machinery and equipment should make an effort to remove large accumulations of plant material and soil with hand tools to make the power washing faster and more effective
    b. Washing of equipment must occur on a landing or road-side before the equipment is moved to another compartment
- Washing is required when equipment is moved from storage to spring or summer jobs after the winter season

[1] Resources called in for a going fire should be cleaned ahead of time or en route. If fire-fighting work on a going fire must move from one compartment to another, washing is exempt.

[2] Graders are exempt from the washing requirement when working in the traveled way of main haul roads, but should be washed periodically at the shop.

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BOTRYCHIUM MORMO (OPHIOGLOSSACEAE), A GLOBALLY RARE ADDITION TO THE VASCULAR FLORA OF ONTARIO

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ABSTRACT

Botrychium mormo W. H. Wagner is reported as an addition to the vascular flora of Ontario from the Thunder Bay District. Described in 1981, this diminutive species of rich northern hardwoods in the Great Lakes–St. Lawrence forest region has been named Little Goblin Fern, because of its peculiar whitish or pale yellow colouration and its tendency to remain hidden under leaf litter in dark shade. It is globally rare, found sporadically in portions of Michigan, Minnesota and Wisconsin, with several disjunct sites in Québec. Its discovery in novel habitat north of the range of its characteristic forest canopy associates of *Acer saccharum* Marshall, *Tilia americana* L., and *Fagus grandifolia* Ehrhart suggests it may occur more widely in the region, and brings the number of globally rare moonworts present along Ontario's north shore of Lake Superior to six species.

INTRODUCTION

Botrychium mormo W. H. Wagner is reported as an addition to the vascular flora of Ontario. Aptly named the Little Goblin Fern due to its white to pale yellow colouration and its tendency to remain hidden under forest leaf litter in dark forest interiors, this species was described in 1981 from the type locality in Clearwater County, Minnesota (Wagner and Wagner 1981). Known only from scattered sites in Minnesota, Wisconsin, Michigan and Québec, its small global range and sensitivity to industrial forestry operations support a global status of Vulnerable (G3, NatureServe 2018). The newly discovered population in Ontario (Figure 1) represents the most northerly location of this species in the Great Lakes basin, beyond the current native range of its characteristic forest canopy associates, *Acer saccharum* Marshall, *Tilia americana* L., and *Fagus grandifolia* Ehrhart. At least ten individuals were found along the edge of an old forest access road through moist second growth forest dominated by *Betula papyrifera* Marshall, with *Populus tremuloides* Michaux and *Abies balsamea* (L.) Miller. Shrubs at this location included *Acer spicatum* Lamarck, *Salix bebbiana* Sargent, and *Diervilla lonicera* Mill. Herbaceous plants growing adjacent to *B. mormo* individuals included *Equisetum sylvaticum* L., *Mitella nuda* L., *Petasites frigidus* (Aiton) A. Gray, *Botrypus virginianus* (L.) Michaux, and *Botrychium minganense* Victorin. Scans of two stems collected from the population are represented in Figure 2.

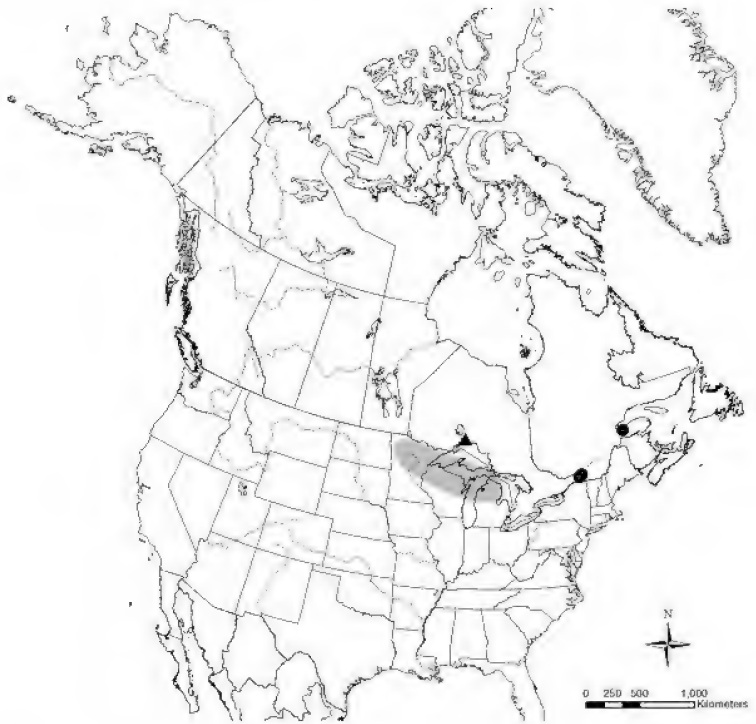

FIGURE 1. Global range of *Botrychium mormo*. The Ontario site on the north shore of Lake Superior is represented by a black triangle. Black circles represent disjunct locations in Québec.

DISTRIBUTION AND ECOLOGY

Botrychium mormo (Little Goblin Fern), also known as Goblin Fern, Goblin Moonwort, and Botryche petit-lutin, is a small perennial fern of rich mesic northern hardwood forests, where it is found in deep leaf mold in mid-aged to mature and old-growth stands of *Acer saccharum, Tilia americana*, *Fraxinus nigra* Marshall, and *Fagus grandifolia* (Wagner and Wagner 1993; Johnson-Groh and Lee 2002). It has rarely been recorded from mesic boreal forest with oak (*Quercus* sp.), birch (*Betula* sp.), maple (*Acer* sp.) and aspen (*Populus* sp.) or from lowland hardwood conifer forest with aspen, fir, and birch (Casson et al. 2002). *Botrychium mormo* is sporadically distributed in several Great Lakes states (Figure 1) including portions of Minnesota (where it reaches its highest density), Michigan, and Wisconsin (Wagner and Wagner 1993), and is also known from three sites in Québec (Tardif et al. 2016; J. Labrecque pers. com. 2018), where it occurs with *Acer saccharum* and other canopy associates such as *Acer rubrum* L., *Fagus grandifolia*, *Ostrya virginiana* (Miller) K. Koch, *Betula*

FIGURE 2. *Botrychium mormo*, unmounted, from east of Nipigon, Thunder Bay District, Ontario (*Brinker 7131*). Photo by Samuel Brinker.

papyrifera and *Betula alleghaniensis* Britton (Wagner and Wagner 1990a; Natural Heritage Data Center of Quebec 2001).

As with other species of *Botrychium*, mature sporophyte plants of *B. mormo* annually produce a solitary upright leaf usually less than 8 cm in height. The above-ground portion of the mature leaf is divided into two axes: (i) the trophophore, the photosynthetic segment leaf (also known as the sterile segment), and (ii) the sporophore, the spore-producing segment (also known as the fertile segment) bearing numerous globous sporangia. The trophophore is small (up to 2.5 cm), the blade shiny, stout and succulent, pale yellow, yellow-green to green, linear to linear-spatulate, usually with 2–4 angular triangular or squarish lobes that are entire to shallowly crenate (Wagner and Wagner 1993; Farrar et al. 2017). The sporophore is 2.4–7.5 cm tall and 0.2–3.5 times the length of the trophophore, the spore bearing portion is commonly branched in the lower third, and the sporangia are relatively large and sessile to slightly embedded in the branch. Leaves appear from an underground stem as early as June, and emergence from different plants can continue late into the fall (Wagner and Wagner 1993).

A significant portion of the life history of *Botrychium mormo* is spent belowground. The sporophyte develops from tiny underground gametophytes that pro-

duce male and female reproductive structures (gametangia) containing sperm and eggs respectively, which, upon fertilization, produce a juvenile sporophyte that takes several years to produce a leaf-bearing apex and which throughout this time, relies heavily on mycorrhizae for development and overall fitness (Johnson-Groh et al. 2002). Plants are highly seasonal and typically remain dormant during suboptimal growing conditions, making detection difficult (Johnson-Groh et al. 2002).

DISCUSSION

The upper Great Lakes basin is a well-known centre of *Botrychium* diversity, and *B. mormo* is endemic to the region (Wagner 1988; Wagner and Wagner 1990b; Zika et al. 1995). The north shore of Lake Superior in Ontario, which is known to harbour 11 species of *Botrychium* other than *B. mormo*, has the richest and most diverse moonwort flora in the province (Cody and Britton 1989; Wagner and Wagner 1993; Gilman et al. 2015; Thunder Bay Field Naturalists 2015). The type locality of *B. pseudopinnatum* is from Angler Settlement east of Marathon (Wagner and Wagner 1990b). The discovery of *B. mormo* brings the total here to 12 species, which constitute almost half of all the described taxa of *Botrychium* in North America. Six of the twelve moonwort species found in the region are globally rare. A list of all moonwort species currently known from the Lake Superior region of Ontario along with the global and provincial conservation status of each is provided in Table 1. Many have similar habitat preferences and tend to co-exist as mixed populations. The population of *B. mormo* reported here co-occurred with *B. minganense*.

The restricted range and complex life history of *Botrychium mormo* are key

TABLE 1. Moonwort (*Botrychium* spp.) species present along the north shore of Lake Superior in the province of Ontario, Canada, along with the global (Grank) and provincial (Srank) conservation status ranks of each (as assigned by NatureServe 2018).

Scientific Name	Common Name	Grank	Srank
Botrychium angustisegmentum (Pease & Moore) Fern.	Narrow Triangle Moonwort	G5	S3
Botrychium ascendens W.H. Wagner	Upswept Moonwort	G3	S1S2
Botrychium campestre W.H. Wagner & Farrar	Prairie Moonwort	G3G4	S1S2
Botrychium matricariifolium (Doll) Braun ex Kock	Daisy-leaved Moonwort	G5	S4S5
Botrychium michiganense W.H. Wagner ex A.V. Gilman, Farrar & Zika	Michigan Moonwort	G3	S1S2
Botrychium minganense Victorin	Mingan Moonwort	G5	S4
Botrychium mormo W.H. Wagner	Little Goblin	G3	S1?
Botrychium neolunaria Stensvold & Farrar	North American Moonwort	GNR	S4S5
Botrychium pallidum W.H. Wagner	Pale Moonwort	G3	S1S2
Botrychium pseudopinnatum W.H. Wagner	False Northwestern Moonwort	G1	S1
Botrychium simplex var. simplex Hitchc.	Least Moonwort	G5T3T4	SU
Botrychium spathulatum W.H. Wagner	Spatulate Moonwort	G3	S2S3

determinants of its current status rank of Globally Vulnerable (G3) (NatureServe 2018). Its reliance on mycorrhizal fungi and its requirement of deep, organic-rich soil typical of mature to old-growth forests and a well-developed leaf litter make it particularly vulnerable to activities that disturb the soil or reduce forest canopy closure. Timber harvesting, especially large-scale forestry operations and recreational activities such as off-road vehicle use that disturb or compact the soil or alter soil moisture have been cited as key threats to populations in Minnesota. This is particularly so when such activities occur early in the growth of above-ground stems in June, when the plants are more susceptible to disturbance than later in August or September, when the plants are senescing (Casson et al. 2002; Minnesota Department of Natural Resources 2018). Concerns over these threats as well as emerging ones from invasion of habitat by non-native earthworms which alter sensitive forest soils and reduce leaf litter have led to *B. mormo* being listed as Endangered in Wisconsin (Wisconsin Department of Natural Resources 2018), and Threatened in Michigan and Minnesota (Michigan Natural Features Inventory 2018, Minnesota Department of Natural Resources 2018). In Québec, it is currently ranked Critically Imperilled (S1) and likely to be listed (Tardif et al. 2016). Its discovery here in second growth forest north of the natural ranges of *Acer saccharum*, *Tilia americana* and *Fagus grandifolia* is noteworthy, although it has also been documented in relatively young second-growth maple stands in Michigan (Penskar and Higman 1996). It is hoped the information presented here on *B. mormo*, including habitat preference, morphology, and phenology, will aid in the search for new sites in the Great Lakes region. If additional populations are discovered, however, it is expected that *B. mormo* will remain a rare element of the regional flora.

DIAGNOSTIC CHARACTERS

The pale colouration and the stout, succulent stem, as well as its restriction to closed-canopy northern hardwoods, make it unlikely that *Botrychium mormo* would be mistaken for most other moonworts in the Great Lakes region. It is most likely to be confused with *B. tenebrosum* A.A. Eaton, which is most frequently found in open meadows (Farrar et al. 2017) but can also be found in moist forests in the region. Shade plants of *B. tenebrosum* tend to appear more slender and lax (vs. succulent and stiff) and to have a shorter trophophore stalk. The squarish, often coarsely toothed, outer pinnae margins of *B. mormo* contrast with those of *B. tenebrosum*, which are more rounded and with a smooth or entire outer margin. The tip of the sterile segment is usually toothed or deeply cleft, unlike the mainly undivided and entire tip of *B. tenebrosum*. Furthermore, forest plants of *B. tenebrosum* tend to be found in moister locations, often near the border of vernal pools where more light is available than deep within mesic hardwood forests (Wagner and Wagner 1981) hence the common name Swamp Moonwort, rather than in deep leaf litter under mature trees in closed deciduous forests.

SPECIMEN CITATION

Ontario, Thunder Bay District: 44 km east of Nipigon, 2.5 km west of Ault Lake, in moist *Betula papyrifera–Acer spicatum* second growth deciduous forest with *Abies balsamea*, *Salix bebbiana*, *Equisetum sylvaticum, Mitella nuda*, *Botrychium minganense* and *Botrypus virginianus*, August 9, 2018, *Brinker 7131* (DAO).

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THE FIRST OCCURRENCE OF THE COCCOID GREEN ALGA *BORODINELLA POLYTETRAS* MILLER IN NORTH AMERICA (MICHIGAN)

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ABSTRACT

The coccoid green alga *Borodinella polytetras* Miller is reported for the first time in North America. *Borodinella polytetras* was collected from rock scrapings at Gull Lake in Kalamazoo County, Michigan. The species has been previously reported from three sites in Europe, Iceland, and one in Asia.

KEYWORDS: *Borodinella*, Chlorococcales, Chlorosarcinales, epilithic algae

INTRODUCTION

The nonmotile coccoid green algae belonging to the Division Chlorophyta are diverse, both morphologically and ecologically. They are divided into six classes and ten orders (Shubert and Gärtner 2015), and their environments range from freshwater to marine habitats. At a quick glance, these organisms, commonly called "little green balls," might all look alike. However, detailed and careful observations reveal stable and distinct morphological characters that separate many of the genera from each other (Prescott 1978; Dillard 2008). Species identification is even more difficult. Although the taxa are nonmotile in the vegetative stage, some species produce flagellated or quiescent stages during their life cycle. In some genera, culturing may be necessary, along with electron microscopy (TEM or SEM) or even molecular genetics, to make a final identification, especially at the species level (Lemieux et al. 2014; Štenclová et al. 2017).

Previous investigations by Wujek and co-workers from Michigan have revealed a diverse algal flora in the state and that have resulted in the descriptions of new genera and species and new state and national records (Wujek 1996, 2003, 2006, 2007, 2009, 2012, 2013, 2017a, 2017b, 2018; Wujek and Thompson 2002, 2003, 2008, 2012; Thompson et al. 1996; see Wujek and Igoe 1989 for extensive additional citations). This paper reports the first occurrence of the chlorococcoid green alga *Borodinella polytetras* Miller (1927) from Michigan and from North America.

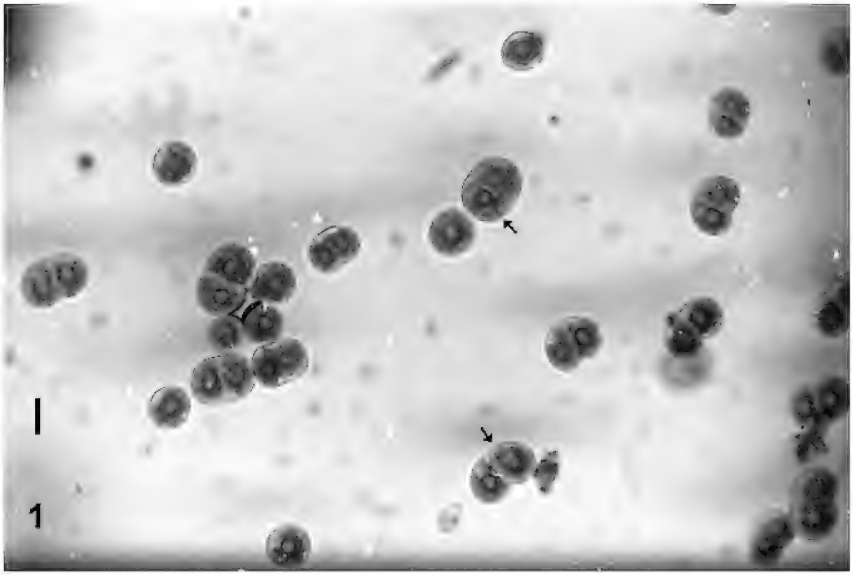

FIGURE 1. *Borodinella polytetras*. Solitary and dividing cells with chloroplasts possessing radiating outgrowths (arrow). Scale = 10 μm.

METHODS AND MATERIALS

Samples containing *Borodinella polytetras* were collected in June 1976 from rock scrapings at the beach in front of Michigan State University's biological station at Gull Lake in Kalamazoo County, Michigan. Observations were made from freshly collected material in strewn preparations with an A.O. Spencer microscope (bright field only) at time of sampling and a Zeiss Photoscope II light microscope using BF field, phase contrast, and Nomarski interference contrast in the laboratory. A formalin preserved sample has been deposited in the Central Michigan University herbarium (CMC). The three reliable characteristics used by Starr (1955) in identifying green chlorococcalean algae were used in distinguishing *Borodinella* from other fresh-water coccoid forms. In an attempt to place the alga into culture, I returned 15 years later, but I found no evidence of its presence in rock scrapings.

OBSERVATIONS

The cells are globose and solitary, although some were observed in tight aggregates during the course of asexual reproduction (Figure 1). The chloroplast is axial, stellate, and often with radial outgrowths (Fig. 1, arrows). The cells from my collections were primarily epilithic, but a few were observed to be neustonic (floating on the surface of the water). I did not observe the tri-, tetra-, or many-celled aggregates observed or reported by some researchers (Korshikov 1953; Fritsch and John 1942; Bourrelly 1966) or any zoospore reproduction, as I did not have the alga in culture.

DISCUSSION

Borodinella polytetras is cited by Shubert and Gärtner (2015) as one of 76 coccoid genera that are "suspected" to occur in North America, but that "are not commonly encountered in aquatic samples". Their report, which is a treatment of green coccoid genera, describes and illustrates over 200 genera that occur in North America. My observation of *B. polytetras* from Gull Lake (Figure 1) represents the first report of this species from North America. It had previously been reported from only five sites, three of them in Europe—Ivanovo Province, Russia, the type location (Miller 1927), Great Britain (Fritsch and John 1942), and Georgia (Barinova et al. 2011)—and one each from Iceland (Broady 1982) and Bangladesh in southern Asia (Aziz and Tanbir 2003; Ahmad et al. 2008). *Borodinella polytetras* is currently the only species recognized in the genus (Guiry 2017).

There has been some confusion as to the order and family placement of *B. polytetras* (Table 1). Most of this uncertainty has been in regard to which order of green algae it belonged to: Chlorosarcinales or Chlorococcales. It was not until Groover and Bold (1969) provided a firm basis for distinguishing between the two orders that characters were defined in recognizing two separate orders. The chlorococcacean taxa do not exhibit desmoschsis (vegetative cell division by the formations of common cross walls) and the chlorosarcinacean taxa do. Now that *Borodinella*'s distinctive cell division is used in separating it from the order Chlorococcales, family Chlorococcaceae into its presently accepted order Chlorosarcinales, the family Borodinellaceae first described by Korshikov (1953). As *Borodinella* is monotypic, its identification using light microscopy is easily made from its most closed related genus *Pseudotrebouxia*. Thus its identification from other member of the Chlorosarcinales is made more easily without the necessity of having to culture it for any of the extensive laboratory procedures described above.

Perhaps because my samples were taken in late spring when water temperatures are relatively lower than the higher summer temperatures, environmental conditions had not yet favored the *Borodinella* cells to develop beyond their uni- and di-ad stages. In addition to the cell arrangements I observed, other researchers have observed tri-, quatra-celled, and eventually aggregate colonies,

TABLE 1. Changes in the order and family classification of Borodinella since its original description.

Author	Order	Family
Miller (1927)	Protococcales	Protococcaceae
Fritsch and John (1942)	Chlorococcales	Chlorococcaceae
Korshikov (1953)	Vacuolales	Borodinellaceae
Bourrelly (1966)	Chlorococcales	Chlorococcaceae
Grover and Bold (1969)	Chlorosarcinales	Chlorosarcinaceae
Tschermak-Woess (1982)	Chlorosarcinales	Chlorosarcinaceae
Fott (1983)	Chlorosarcinales	Chlorosarcinaceae
Komarék and Fott (1983)	Chlorosarcinales	Chlorosarcinaceae
Aziz and Tambir (2003)	Chlorosarcinales	Borodinellaceae
This study	Chlorosarcinales	Borodinellaceae

particularly in cultured material (Miller 1927; Fritsch and John 1942; Aziz and Tanbir 2003).

The following key distinguishes between *Borodinella*, and similar green coccoid green algae, of which only the last two in the key below have been observed in North America (Guiry 2017). The first two genera in the key, as was *Borodinella* in this report, are cited by Shubert and Gärtner (2015) as one of 76 coccoid genera that are "suspected" to occur in North America. It possesses an axial chloroplast, frequently lobed or possessing radiating outgrowths. A single pyrenoid is centrally located within the chloroplast. Although I did not observe any zoospores, they are biflagellate with the cell bearing a papilla (Fritsch and John 1942).

Key to the genera in the coccoid green alga family Borodinellaceae

1. Cells coccoid or forming a filamentous thallus in culture ..... *Botryokoryne* Reisigl
1. Cells unicellular to pseudoparenchymatous 2
   2. Cells spherical to slightly ovoid, cells attached to substrate by posterior colorless parts ..... *Chloroplana* Hollerbach
   2. Cells not as above. 3
3. Lobes of the chloroplast possessing radiating, sometimes long outgrowths up to the cell wall ..... *Borodinella* Miller
3. Axial chloroplast on the edge, wavy to irregularly lobed; lobes +/- short, do not reach to cell wall ..... *Pseudotrebouxia* Archibald

Hopefully this brief note will alert other Michigan phycologists, limnologists, or individuals conducting environmental studies to examine their samples a little more closely.

ACKNOWLEDGMENTS

I acknowledge the late Dr. R. H. Thompson for his confirmation of the alga's identification, Philip Oshel of the Imaging Facility at Central Michigan University and Brian Roberts for assistance in the preparation of the figure. Anonymous reviewers, and especially the editor, Dr. M. Huft, are acknowledged for their constructive comments.

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IN MEMORIAM

NEIL A. HARRIMAN
1938–2018

Editor's Note: Neil A. Harriman served as the editor of *The Michigan Botanist* (now called *The Great Lakes Botanist*) from 1998 to 2005. We are pleased to publish this memorial by one of his students, Thomas L. Eddy.

Neil Arthur Harriman, teacher and scientist, died at home on December 7, 2018 after a rather lengthy decline in his health.

The author (left) with Neil A. Harriman attending the Ripon College sesquicentennial commencement in 2001. Photo credit: Linda C. Eddy.

Neil A. Harriman was born on August 1, 1938 in St. Louis, Missouri, the only son of Ruth and John Harriman. He grew up in St. Louis along with his older sister, Ruth. Neil received his Bachelor of Arts from Colorado College, Colorado Springs, Colorado, in 1960, followed by a Doctor of Philosophy in Biology from Vanderbilt University in Nashville, Tennessee, in January 1965.

While at Vanderbilt, Neil met Bettie Ralph, and they were married on July 13, 1963. Together, they moved to Oshkosh, Wisconsin, in September 1964 when Neil joined the Biology Department faculty at University of Wisconsin-Oshkosh (UWO), primarily to teach botany classes and conduct research in plant taxonomy. Neil remained at UWO until his retirement in May 1998.

Neil was a dedicated teacher and found great satisfaction, not only in teaching plant taxonomy, but also in assisting students to become critical thinkers and life-long learners. His research work of collecting, identifying, and conserving plants was paramount and was a pleasure to him. When Neil arrived on campus in 1964, the herbarium facility in Halsey Science Center was scarcely more than a room with cabinets waiting to be filled with dried, identified, and properly labeled plants arranged in a systematic fashion. Today the herbarium houses almost 125,000 specimens from around the world, including over seventy type specimens. Following Neil's retirement, the university named the herbarium in his honor. The Neil A. Harriman Herbarium contains not only plant specimens, but also Neil's extensive personal botanical library as well.

Neil belonged to numerous botanical societies during his career, including the American Society of Plant Taxonomists, for which he served a three-year term as Secretary and Program Chairman, and the International Association for Plant Taxonomy. His combined love of plants and language ensured updated and correct nomenclatural changes that were regularly reported.

Neil also served as Editor of *The Michigan Botanist* for many years, and as a reviewer and author for the Flora of North America project. During his professional career, Neil's contributions to botany included numerous published scientific papers in the journals of these societies. In addition, his colleagues have named three species in his honor: *Flyriella harrimanii* R. M. King & H. Rob., *Lundellianthus harrimanii* Strother, and *Phyllanthus harrimanii* G. L. Webster.

During his 34 years as a member of the UWO faculty, Neil received a number of awards and recognitions. He was awarded the Citation as an Outstanding Teacher for the school year 1973–74. In May 1986, Neil was named a John McNaughton Rosebush University Professor for Excellence in Teaching and Professional Achievement. In 1993 he received the UWO Endowment for Excellence–The TRISS Endowed Professorship. Upon his retirement in 1998, Neil was named Professor Emeritus of Biology and Microbiology at UWO by the Board of Regents, whereupon he continued to work in the herbarium as long as his health allowed.

Neil's joy of editing the written word extended beyond botany, as did his willingness to help out when needed. During his retirement, Neil joined his wife Bettie as co-editors of the quarterly journal, *The Passenger Pigeon,* of the Wisconsin Society for Ornithology from 2003 to 2014. He also contributed his editing skills to the production of the *Atlas of the Breeding Birds of Wisconsin,* a 600-page book published by the Wisconsin Society for Ornithology in 2006. Perhaps most importantly, he served for eight years as editor of *The Michigan Botanist*. Whether as an editor, teacher or scientist, Neil was a stickler for minutiae and doing it correctly the first time—his work ethic was impeccable.

Forty years ago, as a young graduate candidate at the University of Wisconsin-Oshkosh, I was encouraged by Neil to conduct a systematic study of the vascular flora of Green Lake County, an under-collected area of the state. My thesis research and continuous association with Neil resulted in a profound change in my life trajectory, both personally and professionally.

Apart from our independent plant collecting, Neil and I participated in numerous botanical outings organized by the Botanical Club of Wisconsin. Neil's taxonomic knowledge was encyclopedic. He exercised a superlative command of language and proper use of grammar. Whether in lecture or private conversation, he could turn what first appeared to be a collection of unrelated facts into a coherent, relevant lesson, frequently accompanied by humorous observations.

Neil was an unpretentious and modest person, preferring not to draw attention to himself. In 2009, the herbarium that Neil founded in 1964 was dedicated in his honor: the Neil A. Harriman Herbarium. While such an honor might induce one to grandstand, Neil avoided the opportunity entirely at this ceremonious tribute. In fact, it is fair to say that Neil would disapprove of this memoriam and the accompanying accolades.

The natural world was held in reverence by Neil. Whether botanizing a nat-

ural area, roadside right-of-way, or a parking lot, his eye was trained on the ground. Besides collecting new plant records, Neil regularly collected and properly disposed of other people's litter.

Neil gifted generously to his local animal shelter. He held a tender spot for cats and dogs waiting to be adopted. On numerous occasions I witnessed a similar mindfulness in Neil toward other peoples' lives whose unfortunate circumstances were less than ideal. He was generous and big-hearted, contributing to the common good. For all this, I owe Neil a debt of gratitude for his mentorship and unflagging friendship.

Rest in peace Neil A. Harriman, and to borrow a phrase from him when parting: *Thank you for the pleasure of your company.*

——Thomas L. Eddy
426 Walker Avenue
Green Lake, WI 54941

APPENDIX
RESEARCH PUBLICATIONS OF NEIL A. HARRIMAN

Neil did not keep a record of his publications. The following list has been compiled by the author and the editor from available sources and is likely incomplete. Not listed here are a large number of book reviews, primarily in the journals *Economic Botany* and *The Michigan Botanist*.

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NOTEWORTHY COLLECTIONS

NEW RECORDS FOR SOME OLD GRASSES IN WISCONSIN

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WISCONSIN

Apera interrupta (L.) P. Beauv.
Poaceae
Silky Bent Grass, Interrupted Windgrass

Significance of the Report. The third record for Wisconsin of a rare grass first collected in 1981 and not again until 2008 and 2016.

Previous Knowledge. Native to Europe, *Apera interrupta* has been introduced sparingly across North America, with most records from the western states (Allred 2007). The species is rare in Michigan, having been first collected in 1989 (Voss and Reznicek 2012). In the Chicago region, it is known from DuPage County, Illinois and Porter County, Indiana, where first collected in 1992 (Wilhelm and Rericha 2017). *Apera interrupta* has also been known from Ontario, Canada since 1974 (McNeill 1981) and was first collected in Ohio in 1980 (Cusick and Brandenburg 1984). In all of these areas, this species is associated with dry, often sandy and rocky, disturbed soils along trails, railroads, or gravel roads. Only three records are known from Wisconsin, the first having been collected in 1981 in the Village of Sobieski, Oconto County (Solheim and Judziewicz 1984). No further collections were made until 2008, when it was collected on the campus of the University of Wisconsin-Green Bay in Brown County (Judziewicz et al. 2014).

Discussion. The population reported here represents only the third time the species has been collected in Wisconsin and is a significant range extension from the northeastern part of the state. The new population was found growing in a sandy, weedy area near a public beach in Milwaukee, Milwaukee County. The area is directly adjacent to a parking lot not far from the shore of Lake Michigan. This area had seemingly been planted with prairie plants such as *Koeleria macrantha* (Ledeb.) Schult. and *Tradescantia ohiensis* Raf., but also had numerous weeds including *Medicago lupulina* L., *Festuca myuros* L., *Lolium pratense* (Huds.) Darbysh., *Lolium perenne* L., and *Linum perenne* L. Only a few individuals of *Apera interrupta* were found in 2016, but during a subsequent visit to the site in 2017, I recorded at least a dozen individuals of varying sizes; the plants

always occupied bare soil patches that were not overtopped by other vegetation. Easy (1992) reports that in England, this species usually occurs on disturbed, dry soils, where it is normally short in stature. It is apparently not a good competitor, as it tends to disappear from these sites when perennial species become well-established. However, it may persist in the seedbank for long periods of time (Easy 1992). It seems plausible that this species could exist at other locations in Wisconsin, but that it may appear in an area only for a season or two before it is quickly crowded out.

Apera interrupta could be mistaken for a species of *Agrostis* L., but it differs in having firm lemmas, well-developed paleas that are always present, and conspicuous awns.

Specimen Citation. Wisconsin: Milwaukee Co.: Milwaukee, Grant Park, public beach off E. Oak Creek Parkway. Small, sandy-soiled planting area next to parking lot. 42.906993, –87.842276. June 11, 2016, *J. G. Zaborsky 1034* (MIL).

Bouteloua dactyloides (Nutt.) Columbus
Poaceae
Buffalo Grass

Significance of the Report. First collection from Wisconsin in 25 years of a grass native to the Great Plains.

Previous Knowledge. *Bouteloua dactyloides*, long known as *Buchloë dactyloides* (Nutt.) Englm., is a dioecious, perennial grass that is an important component of the shortgrass prairies of North America. Recent phylogenetic analyses have shown that this iconic and distinctive plant is embedded within the New World genus *Bouteloua* Lag. (Peterson et al. 2015). This short, turf-forming grass is native to the Great Plains, from the prairie provinces of Canada through the desert southwest and into Mexico (Snow 2003). It has been introduced east of the Mississippi River in Michigan and Illinois, as well as in Virginia. It was first collected in Michigan in 2002, where it occurs along roadsides (Voss and Reznicek 2012). In Illinois, it has been collected in seven counties in the Chicago region, where it was first discovered in 1973 (Wilhelm and Rericha 2017). This species was first collected in Wisconsin in 1956 from a railroad yard in La Crosse, La Crosse County. It was not collected again until 1980, from along railroad tracks in Muscoda, Grant County. Eleven years later, it was documented by two different collectors from Iowa County. Both of these specimens, housed at MOR, have the same collection date (July 13, 1991). One (*L. Skizas 107*) was collected "4.7 mi north of Barneveld" and the other (*K. Altvatter 9*) from the "jct. of Knutson Rd. and Lakeview Rd." This road intersection is approximately 4.7 mi northwest of the center of Barneveld, and the specimens could conceivably have come from the same population. However, they give differing habitat information: "low ground, cave-fed spring" for the former and "along roadside near xeric woods" for the latter.

Discussion. The new population reported here was discovered in 2016 in Marquette County. While looking for weeds at a highway rest stop, I came across a strange-looking turf growing next to the off-ramp that leads from the highway

into the parking lot. Upon closer inspection, I realized that the grass was flowering and recognized it as male plants of *B. dactyloides*. I revisited the site in 2017 and was able to find both male and female plants growing in the same place as the previous collection. I did not find any other patches at the rest stop. This location is along a major highway (I-39) and the plants could have been introduced via vehicles travelling through the rest stop.

Bouteloua dactyloides is not likely to be confused with any other grass in Wisconsin. It is our only species of grass that is dioecious, and the morphology of the female spikelets is unique. The female spikelets each contain one floret and are borne in groups of three to five, and each individual spikelet is enclosed in a hard burr formed by its glumes. Our only other grass that has a hard burr surrounding its spikelets is *Cenchrus longispinus* (Hack.) Fernald, but that species differs in not forming stoloniferous mats, having spikelets with two florets (one bisexual, the other usually staminate), and burrs formed by highly reduced branches. The burrs of *C. longispinus* are extremely sharp and painful, while those of *B. dactyloides* are not. Staminate individuals of *B. dactyloides* resemble other species of *Bouteloua* in Wisconsin, but readily differ in their short, stoloniferous habit and unisexual florets.

Specimen Citation. Wisconsin: Marquette Co.: Forming a large turf alongside a highway off-ramp at Rest Area 82, along I-39, north of Westfield. 43.947704, –89.483775. May 30, 2016, *J. G. Zaborsky 983* (MIL, UWSP).

Bouteloua gracilis (Kunth) Lag. *ex* Griffiths
Poaceae
Blue Grama

Significance of the Report. First collection from Wisconsin in 40 years of a grass native to the Great Plains.

Previous Knowledge. *Bouteloua gracilis* is native to the Great Plains region, extending from Canada to central Mexico (Wipff 2003). This species is considered introduced in Wisconsin and was first collected in 1936 from along a railroad in Richland County. In southern Wisconsin it was collected only three more times: in Juneau County in 1940, in Dane County in 1950, and in Green County in 1961. All of these collections were from along railroads as well. *Bouteloua gracilis* was collected a handful of times between 1964 and 1977 in the village of Whiting in Portage County in a 30-acre plot known locally as the Whiting Triangle (Freckmann 1978), but it was not relocated in 2012 (Judziewicz et al. 2014). This location harbors many interesting prairie plants at the edge of their Wisconsin ranges, but the location is adjacent to a railroad and the *B. gracilis* population was probably introduced there. Fassett (1951) maps collections of this species from both St. Croix and Pierce counties, but no vouchers to corroborate its existence in those counties have been found. Other western prairie species are native to that area of Wisconsin, and *B. gracilis* could potentially have been native there as well.

Discussion. The new population reported here was discovered in 2017 in Marquette County. While revisiting the location of *Bouteloua dactyloides* that I

had discovered in 2016 (see above), I found *Bouteloua gracilis* growing in the same area. The *B. gracilis* plants were growing within the *B. dactyloides* turf and conceivably could have been introduced with the latter. *Bouteloua gracilis* could be confused with the native *B. hirsuta* Lag., but differs by lacking a naked bristle-like extension of the spike rachis.

Specimen Citation. Wisconsin: Marquette Co.: Growing in a lawn along a highway off-ramp at Rest Area 82, along I-39, north of Westfield. 43.947704, –89.483775. July 05, 2017, *J. G. Zaborsky 1310* (MIL, OSH, UWGB, UWSP, WIS).

Festuca myuros L.
Poaceae
Rat-tail Fescue

Significance of the Report. Three new records for a weedy European grass last collected in Wisconsin 45 years ago.

Previous Knowledge. *Festuca myuros* is an exotic grass introduced to North America from Europe (Lonard 2007). It is widespread across the United States, although most records are from the transmountain West and in the Atlantic and Gulf coastal plains. It was previously placed in the genus *Vulpia* C.C. Gmel. as *V. myuros* (L.) C.C. Gmel. This weedy annual was first collected in Wisconsin in 1914 in Sheboygan County (Shinners 1940). It was not collected again in the state until 1970 in Winnebago County (Harriman 1971). In Michigan, it is reported as "rarely established," having been first recorded in 1976, and is currently known from only two counties (Voss and Reznicek 2012). It is known from scattered localities in the Chicago region, having been first collected there in 1973 (Wilhelm and Rericha 2017).

Discussion. Three new localities for *Festuca myuros* are reported here, two of which are county records. The first collection is from Winnebago County, in the Village of Fox Crossing. A few small individuals were found growing in gravelly soil at the bottom of a hillside. The Friendship State Trail runs along the top of this hill and is built on the bed of an old railroad. The old railroad ballast makes up the majority of the hillside and includes other weedy species such as *Capsella bursa-pastoris* (L.) Medik., *Cerastium fontanum* Baumg., *Equisetum arvense* L., and *Dracocephalum parviflorum* Nutt. A year later, I found *F. myuros* in Milwaukee County at the same location as *Apera interrupta* (see above). Here, the plants were quite robust, multi-stemmed, and reaching about 40 cm in height. The third locality was discovered in Rock County in 2017, where the plants were growing on a sandy hillside with crumbling sandstone outcrops. This area has a nice community of remnant dry prairie that is being actively managed. The plants at this locality were numerous but small in stature. While the first two populations were discovered in weedy sites where they may not persist long-term, the Rock County population has the potential to be detrimental to the surrounding area. *Festuca myuros* has been shown to negatively impact the survival of native perennial grasses in California (Brown and Rice 2000), which suggests that it could spread throughout this location and possibly suppress the native vegetation. Dry prairie and rock outcrop species such as *Lechea tenuifolia* Michx.,

Selaginella rupestris (L.) Spring, *Tradescantia ohiensis*, and *Dichanthelium columbianum* (Scribn.) Freckmann, among others, all occur here in a rather small area.

Festuca myuros could occur elsewhere in the state but may be overlooked due to its normally short stature, annual habit, early-blooming period (mid-May), and readily-disarticulating spikelets. It most closely resembles the native *Festuca octoflora* Walter, but can be distinguished from that species by its lower glume that is less than half as long as the upper glume. In the specimens of *F. myuros* collected in Wisconsin so far, the lemmas also have awns that are much longer than those found in *F. octoflora*.

Specimen Citation. Wisconsin: Winnebago Co.: Village of Fox Crossing, Fritse Park. Growing at bottom of trail at edge of lawn on north side of Friendship State Trail with *Cerastium fontanum, Equisetum arvense*. 44.206459, –88.471728. June 21, 2015, *J. G. Zaborsky 668* (OSH, UWSP, WIS); Wisconsin: Milwaukee Co.: Milwaukee, Grant Park. Large, tufted plant growing in a gravelly planted area beside beach parking lot. Growing with *Apera interrupta, Koeleria macrantha, Lolium perenne, Medicago lupulina*. 42.906993, –87.842276. June 11, 2016, *J. G. Zaborsky 1042* (MIL); Wisconsin: Rock Co.: Evansville, Magnolia Bluff County Park. Numerous plants growing in an open area on a sandy hillside with *Tradescantia ohiensis, Potentilla recta, Lechea tenuifolia*. 42.730691, –89.355459. June 13, 2017, *J. G. Zaborsky 1245* (WIS).

Sporobolus schoenoides (L.) P.M. Peterson
Poaceae
Swamp Pricklegrass, False Timothy

Significance of the Report. The first collection in 45 years of a rare, halophytic grass in Wisconsin.

Previous Knowledge. This Eurasian grass was long-known in older manuals as *Crypsis schoenoides* (L.) Lam. or *Heleochloa schoenoides* (L.) Host. *Sporobolus schoenoides* is an annual grass that in the US is most abundant in California but is also known from scattered collections in the Midwest and Northeast (Hammel and Reeder 2003). In California, it is most commonly found around drying lake margins and vernal pools. In the Midwest and Northeast, it is associated with waste ground, especially around railroad tracks and saline areas. In the Chicago region, it was first collected in 1893 and is known from several counties (Wilhelm and Rericha 2017). The species is rare in Michigan, having been first collected in 1930 (Voss and Reznicek 2012), where it often associates with other "highway halophytes" such as *Spergularia media* (L.) Griseb., *Muhlenbergia asperifolia* (Trin.) Parodi, and *Centaurium pulchellum* (Sw.) Hand.-Mazz. (Reznicek 1980). *Sporobolus schoenoides* was first collected in Wisconsin in 1936, in Milwaukee, Milwaukee County (Shinners 1940). It was then collected throughout Milwaukee between 1937 and 1940 along railroad tracks and in vacant lots; it was collected in similar habitats in Fond du Lac, Fond du Lac County in 1940 and Racine, Racine County in 1942. It was not collected again until 1972 in Sturtevant, Racine County.

Discussion. The collection reported here is the first for *Sporobolus schoenoides* in 45 years and represents a county record. Numerous individuals were found growing in pavement cracks and crushed gravel edges of a parking lot at a highway rest stop along I-94 between Johnson Creek and Aztalan in Jefferson County. The plants were growing with *Plantago major* L. and *Digitaria sanguinalis* (L.) Scop., which are typical pavement crack plants. Ditches and pavement edges throughout the rest stop contained numerous halophytic plants, attesting to the fact that the area must have heavy salt application in winter. It seems plausible that this low-growing grass could occur in other parts of the state, but in areas that are not easily accessible such as railroad yards and highway edges.

Specimen Citation. Wisconsin: Jefferson Co.: Johnson Creek, I-94 Rest Area 14. Common in pavement cracks with *Digitaria sanguinalis* and *Plantago major*. 43.086757, –88.823885. October 11, 2017, *J. G. Zaborsky 1485* (MIL, OSH, UWGB, UWSP, WIS).

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BOOK REVIEW

Gerould Wilhelm & Laura Rericha. 2017. *Flora of the Chicago Region*. Indiana Academy of Science, Indianapolis. xviii + 1372 pp., hardcover $125.00. ISBN 978-1-883362-15-7. A planned ebook version is not yet available.

The southern end of Lake Michigan boasts the greatest floristic diversity in the Great Lakes region. Not least among the factors that promote this richness is the presence of numerous specialized habitats in the area. Some of these once covered vast tracts in the Midwest, but are now globally rare and present only as remnants. It is appropriate, then, that this area has long been covered by excellent floras. An early major effort in this regard is *Flora of the Chicago Region* by H. S. Pepoon (Pepoon 1927). Pepoon, a high school teacher, had spent many years studying the flora and preparing the book. For purposes of Pepoon's flora, the "Chicago Region" was defined as a semicircular area centered just offshore of Chicago, the perimeter of which extended from the moors north of Waukegan, Illinois, past the cities of Zurich, Elgin, and Joliet, Illinois, then into Indiana near Crown Point, running north of Valparaiso, and ending at what is now the Indiana Dunes State Park. The flora was primarily a listing of the plants; there were some keys covering some groups of plants, but by no means all; the entries for the individual species contained brief habitat description and occasionally a brief descriptive phrase. A still valuable feature of Pepoon's flora is an introductory section of nearly 140 pages describing all the major habitats and floristic regions in the area and illustrated by numerous photographs of the various habitats. This was soon complemented by Donald Culross Peattie's *Flora of the Indiana Dunes* (Peattie 1930), which covered two rather ill-defined areas, the "High Dunes Country," extending along the shore of Lake Michigan from Miller (a section of Gary, Indiana) to the Michigan-Indiana state line, and the "Calumet District," described as "a great sandy and marshy tract to the west" extending to the Indiana-Illinois state line. In an important advance over Pepoon, Peattie's flora had full keys and brief descriptions of all taxa covered, which serve as an important complement to the keys in the effort to identify a plant.

The individual who arguably dominated the floristic study of the Chicago region for half a century, Floyd Swink, appeared on the scene right after World War II. Having had an acute interest in plants since his high school days in the 1930s, he then began an association with Dr. Julian Steyermark, a renowned botanist at the Field Museum, who tutored him in botanical matters for the next 13 years (Mohar 2002). Over the ensuing years, Swink learned quickly and intensively explored the flora of the Chicago region. His first book on the flora was *A Guide to the Wild Flowering Plants of the Chicago Region* (Swink 1953). Not a flora as that term is usually understood, this book is rather an extended key to the flowering species (other than graminoids and ferns) in the Chicago region, defined as a semicircular area centered on Chicago and encompassing an area somewhat larger than that recognized by Pepoon (1927). The key uses a device invented by

Swink that is quite different from other keys one may be familiar with, later described by Swink as a "radical departure," but "highly successful" (quoted in Mohar 2002). The device was an initial list of 26 characteristics, each given a letter from A to Z, divided into 6 categories. The user with an unknown plant would compare the characteristics in the list to create a 6-letter phrase, such as BFJQVX, then go to that phrase in an alphabetical listing of all possible combinations where one or more plants fitting those characteristics would be further distinguished. Before long, Swink took a different tack and published a checklist of all known plants in the Chicago region, now encompassing 22 counties, three in southeastern Wisconsin, 11 in northeastern Illinois, seven in northwestern Indiana, and one in southwestern Michigan (Swink 1969). This area thus was larger than, and encompassed all of, the areas included in all previous floristic publications on the Chicago region. This was the first of what eventually became four editions of *Plants of the Chicago Region*. This edition rapidly sold out, and a second edition was published just five years later (Swink 1974). Both of these editions lacked keys and descriptions and therefore could not be used to identify plants. Instead, they were meant to be used in conjunction with other books that do have those features. They did, however, include habitat data and associated species for each species included as well as distribution maps (a dot in each county in which the species has been recorded to occur) and, in the second edition, flowering dates. Taxa were arranged, not taxonomically by family, as is the case with most floras, but alphabetically by genus, and then by species within each genus.

Early in 1974, Gerould Wilhelm, having just left the army, joined the staff of the Morton Arboretum in Lisle, Illinois, where Floyd Swink was employed. Two years earlier, Wilhelm, having no experience in botany, had enlisted Swink to assist him in assessing certain potential dredging sites for the army and was impressed with the latter's extensive knowledge of all the plants they saw (Greenberg 2002). From then on, Wilhelm worked closely with Swink in preparing the third edition of *Plants of the Chicago Region* (Swink and Wilhelm 1979) and later with the fourth edition (Swink and Wilhelm 1994). Both the third and fourth editions were greatly expanded over previous editions with the addition of identification keys, first to family in the front of the book, then to genus within each family, which appeared alphabetically interleaved with the genera, and finally to species within each genus. But a major addition was a description of the Floristic Quality Assessment, first introduced in these volumes, a methodology devised by Wilhelm to assess the quality of natural areas by assigning all native species in the flora a number from 1 to 10 in order of increasing fidelity to a native habitat and taking the average of all species found in the habitat in question. The higher the average, the greater the quality of the habitat. Ever since, this methodology has been used by botanists and ecologists ever since throughout the Midwest and beyond, as is attested by its use in numerous articles published in the present journal.

With these two editions, botanists, ecologists, and nature enthusiasts at last had an up-to-date means of identifying the plants in the Chicago region and an accurate listing of all the plants in the area, their distribution, and their ecological preferences. But "up-to-date" is a relative term. Beginning around the time of

the publication of the fourth edition of *Plants of the Chicago Region*, there was a ferment in taxonomic botany that continues to this day in which wholesale realignments in the relationships of many groups of plants took place, resulting, in many cases, in changes in the scientific names. By 2017, 23 years after the publication of the fourth edition, so many names had changed, and generic assignments altered, that the 1994 edition was becoming increasingly out-of-date. A new generation of young botanists, ecologists, restoration biologists, and nature enthusiasts had grown up in the meantime for whom the old names were mystifying.

Thus, the appearance early in 2017 of Wilhelm and Rericha's new *Flora of the Chicago Region* was long awaited and enthusiastically welcomed. As the new title indicates, this is not merely a fifth edition of the Plants of the Chicago Region, although in many ways it is in fact a continuation of the earlier works by Swink and Wilhelm. It continues the alphabetical by genus arrangement; it maintains the dot distribution maps for the same 22-county region; and it continues the practice of the earlier volumes of listing numerous plant associates of each species included. But there is much that is new, and what is new justifies the treatment of this volume as a new work in itself. Most importantly, descriptions are provided for every taxon in the flora, the first time a flora covering any part of the Chicago region has contained descriptions since Peattie (1930). Although they are brief, they are concise and cover the essential identifying characteristics, thereby serving as an important confirmation or check on the process of keying out an unknown plant. In addition, excellent and accurate line drawings illustrating important identifying characteristics accompany many of the entries. For the first time in any flora covering this region, and perhaps for the first time in any flora anywhere, many of the entries contain lists of insect, bird, and other animal associates of the plants, whether as pollinators, herbivores, or otherwise. Moreover, these are not always bare-bones listings—often a description of the activities of the animal associates is given. An important feature carried over from the earlier volumes by Swink and Wilhelm that should not be minimized is the inclusion under each taxon of alternative names used for that taxon by any of several older floristic works covering all or part of the same area, including large regional floras that cover the entire northeastern United States and Canada. This can be very useful in comparing the treatment of a taxon here with that offered by other authors.

So, too, much additional information has been added at the front and back of the book. After a detailed Introduction explaining the contents of the book and how to use it, there is a classification of the natural divisions of the floral area, based on geological and vegetational distinctions, accompanied by a full-color map, and a detailed description of each of the many plant communities in the area with 42 color photographs. At the end of the book, there is an index to plant names, including both scientific and vernacular names, and index to the animal names that have been mentioned in the individual species entries, followed by a similar index to rusts, smuts, mildews, and other fungi. A list of all individuals given as authorities for the names in the *Flora* is provided, explaining all abbreviations and giving the birth and death dates of each. Finally, the book concludes with a detailed glossary, 24 color plates, and an extensive bibliography of litera-

ture cited throughout the book. As if that were not enough, the editor who saw this magnificent work through the press, Bill McKnight, asked the senior author to provide an "End Note, a Retrospective and Perspective," which details Wilhelm's 45 years of botanical study in the Chicago region, itself a valuable addition to the history of floristic endeavor in this rich botanical area.

I cannot end, however, without discussing what I view as a significant drawback, and that is the sometimes rather idiosyncratic choices in classification made by the authors. The ferment referred to earlier in taxonomic botany continues, and the end is not in sight. Nevertheless, a number of significant conclusions have been reached that are widely accepted among botanists, and most modern floras incorporate these findings. There is certainly room for some disagreement among authors, even while adhering substantially to the general consensus on classification. The book under review is no different; in large measure, it incorporates modern findings and thereby satisfies the longing for an up-to-date flora of the region. But there are some significant departures that are not explained. For example, the Liliaceae, once treated as a large unwieldy family that was long recognized as unnatural, has in recent decades been pared down to a group of about 15 or 16 genera and about 600 species that has been widely accepted as natural by botanists for more than two decades (see Givnish et al. 2016 and references therein). But Wilhelm and Rericha make it much smaller still, recognizing among local genera only *Erythronium*, *Lilium*, and the non-native *Tulipa* as belonging to the family. Other genera, all but universally recognized as belonging to the core Liliaceae, are relegated elsewhere: *Medeola* to the Trilliaceae, where it clearly does not belong, despite a superficial resemblance to some species of *Trillium*; and *Clintonia* and *Streptopus* to the Convallariaceae, where they keep company with genera that are now conceded to be only distantly related to the Liliaceae and that belong in fact to a separate order, the Asparagales. Similarly, the Scrophulariaceae, formerly a large family widely understood to be unnatural, has also in recent decades been dramatically dismembered, keeping in the core Scrophulariaceae only two local genera, the native *Scrophularia* and the non-native *Verbascum*. The remaining local genera have been moved to several other families, including Orobanchaceae, Phrymaceae, Plantaginaceae, and Linderniaceae. Although this re-arrangement is widely accepted among botanists, Wilhelm and Rericha "acquiesce" in it only to the extent of accepting the transfer of certain genera to the Orobanchaceae, retaining all the rest in their Scrophulariaceae. Despite a lengthy explanation of their choices, it all seems to come down to a matter of taste (or perhaps distaste) rather than a reasoned rejection of the current consensus. The last few decades have also seen the combination of pairs of families that were previously considered distinct, but widely understood to be closely related, such as Apocynaceae/Asclepiadaceae, Boraginaceae/Hydrophyllaceae, Campanulaceae/Lobeliaceae, Papaveraceae/Fumariaceae, and Amaranthaceae/Chenopodiaceae (in each case, the first name of a pair is the name currently used for the combined family). Despite the widespread acceptance of these combinations, Wilhelm and Rericha keep these pairs separate without providing a reason.

At the generic level, perhaps the most egregious departure from current understanding is the recognition of *Jussiaea* as distinct from *Ludwigia*. The authors

state that to "lump this genus with *Ludwigia* certainly is *au courant*, but to do so obfuscates the definitive morphological distinctions: *stamens twice the number of petals and elongate fruits more than twice as long as wide*" (italics in the original). But the current joining of these two genera is not merely "*au courant*." It is based on solid biological grounds. The traditional *Jussiaea* and *Ludwigia* were separated solely on whether there were one whorl of stamens (*Ludwigia*) or two (*Jussiaea*). The distinction in dimensions of the fruit may hold for the local species, but does not do so on a world-wide basis. More than forty years ago, I asked Peter Raven, the world's authority on the family to which these genera belong (Onagraceae), why these genera were joined. He explained that species of *Jussiaea* were each actually more closely related to other species of *Ludwigia* than they were to each other. In other words, to recognize both genera would render both unnatural, or in modern parlance, they would not be monophyletic groups, the most basic criterion in botanical classification for at least the last half century. The inclusion of *Jussiaea* within *Ludwigia* has been the consensus at least since 1955 (Wagner et al. 2007). Similar departures in other genera can be mentioned in passing: *Anemonella thalictroides* (currently *Thalictrum thalictroides*); *Erophila verna* (currently *Draba verna*) (see Al-Shehbaz et al. 2010, who explain that *Erophila* differs from *Draba* in only a single character, which is furthermore unreliable, and that removing *Erophila* from *Draba* would render the latter non-monophyletic).

Both the book under review and the earlier volumes by Swink and Wilhelm are characterized by the virtually complete absence of any reasons given for their taxonomic choices. Rather, differences of opinion are introduced with sentences such as "Some authors consider this species conspecific with *Erophila verna*," or "Some authors call this plant *Thalictrum thalictroides*," or "Some authors include this genus with the Montiaceae." One could easily conclude that, by and large, the taxonomic choices are made on the basis of taste rather than taxonomic reasoning.

None of this gainsays the fact that Swink, Wilhelm, and Rericha are superbly outstanding floristicians and field botanists, who are concerned with the questions of what grows in the flora area, where does it grow, and how do you identify it; what are its ecological and community circumstances. Despite my quibbles about classification, this book remains one of the finest floristic works anywhere. It represents an enormous amount of painstaking field, herbarium, and literature work, and presents with great completeness and accuracy the current knowledge of the flora of the Chicago region, a knowledge that has been, in substantial part, developed by the authors themselves. Again, despite my quibbles, the names and classification used in this book are overwhelmingly in accord with current consensus, and for that reason, although I cannot recommend it as the last word in nomenclature or classification of our local plants (those who need that sort of information can easily find it elsewhere), it is highly recommended to all who have a need for knowing what grows in this area, where it grows, and how to identify it. I live in the area covered by this *Flora*, and I refer to it on an almost daily basis. I have gained a wealth of insight about our local flora from this magisterial work, and I would not be without it.

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——Michael Huft

BOOK REVIEW

Welby R. Smith. 2018. *Sedges and Rushes of Minnesota: The Complete Guide to Species Identification.* Photography by Richard Haug. University of Minnesota Press, Minneapolis. xxi + 667 pp., paperback. ISBN 978-1517902759. $39.95.

Sedges and Rushes of Minnesota is the newest book by author Welby R. Smith, Minnesota State Botanist with the Minnesota Department of Natural Resources. His past guides to orchids (Smith 2012) and trees and shrubs (Smith 2008) of Minnesota are incredible resources, making the release of this book highly anticipated and sought after.

The Cyperaceae (Sedge family) and Juncaceae (Rush family) are closely related families within the order Poales and are often considered two of the most difficult plant families in terms of species identification. Many botanists have been hesitant to take up the challenge. Cyperaceae, with 217 species in Minnesota and nearly 900 native species in North America, is one of the most species-rich and ecologically important plant families in the state and on the continent. Juncaceae, with only 27 species in Minnesota, is much smaller. Both families were long neglected; however, these ecologically important plants have recently been the focus of intensive scientific study, both taxonomic and ecological. Publication of the *Flora of North America* (FNA) Cyperaceae volume (Ball et al. 2002) highlighted many new additions and species concepts with revised treatments. Further study since the FNA treatment has continued to change our understanding. With nearly 250 species present in the state of Minnesota, *Sedges and Rushes of Minnesota* is a valuable and important contribution. Truly a book that botanists throughout Minnesota and the Midwest will want to add to their bookshelves.

As stated by the authors, this is a "complete guide," and, as such, will prove to be useful both in the field and especially back at the microscope where final determination of these difficult groups is often made. The Preface and Introduction provides a brief description of the work and a basic explanation of Minnesota physiography (substrate types and major vegetation zones). Well-crafted dichotomous keys are provided to genus, section (for the genus *Carex*), and ultimately species. The genus and (for *Carex*) section descriptions are concise but informative, while the species descriptions are detailed and focused, clearly the result of countless hours of investigation of Minnesota sedges and rushes, both in the field and in the herbarium. Each species treatment is given two facing pages, one with a written technical description with measurements from Minnesota vouchers and the other with photographs illustrating the habit and diagnostic features of each species.

Examination and verification of more than 25,000 herbarium specimens guided this work. Color distribution maps with dots overlaid on a map of Minnesota's major vegetation zones provide a quick assessment of the species distri-

bution in the state. These distribution maps are original to this work, and on their own would be a major scientific contribution.

While the keys, species treatments, and distribution maps are all top-notch, the incredible photographs set this work apart from other similar guides. Richard Haug provided most of the photos for this guide, and they are outstanding and are fully supported by voucher specimens. Each species has a full page of photographic images, showing the habit as well as details of the inflorescence, spikelets, achenes, scales, and other diagnostic features. Especially noteworthy are the single page spreads showing side-by-side comparisons of all of the *Carex* section *Ovales* perigynia (p. 234), *Carex* section *Stellulatae* inflorescences and perigynia (p. 375), *Carex* section *Vulpinae* perigynia and leaf sheaths (p. 407), *Cyperus* spikelets (p. 422), and *Eleocharis* achenes (p. 461). These full and partial page comparisons are truly works of art, worthy of being framed in any Caricologist's office.

Criticisms of this work are mostly minor and not worthy of much space in this review. My main criticism is the change in layout for the key to sections of *Carex*. Because of the vast number of species of *Carex* these pages will be used more than any of the others. The change from portrait to landscape orientation, in my opinion, makes these pages unnecessarily difficult to use, especially in the field. The lack of common names for species or even for genera is explained and is somewhat understandable. Having said this, I feel that inclusion of common names, especially when they do exist, would make the guide more user-friendly for botanists just learning these difficult groups. Lastly a more complete introduction with information and illustrations of the two families and their genera would broaden the expected audience and make this book more readily usable by beginning botanists or ambitious amateurs.

As expected, this book is thoroughly referenced, clearly written, and beautifully illustrated. Professional botanists throughout Minnesota and the Midwest will definitely want to have this book in their field pack or on their shelf.

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ANNOUNCEMENT

INDEX TO *THE GREAT LAKES BOTANIST / THE MICHIGAN BOTANIST*

Suzi Teghtmeyer, Agriculture, Botany and Forestry Librarian at Michigan State University Libraries, has assembled a table of contents-level index of volumes 1–57 of *The Great Lakes Botanist* / *The Michigan Botanist*. This index includes citation information for 1,864 entries of articles, announcements, regularly featured articles, biographies, and more. As an enhancement to the 245 generic "Book Review" entries found in the tables of contents, the book review entries in the index also include the title and author of the reviewed item in the title field, thereby identifying what is reviewed. Also, "On the cover" descriptions are included for all covers.

What is not included are lists of all species and geographic locations named in the text of each article. Some articles may have some of that content in the field "Author's Keywords," but that would include only a minority of the articles. A better resource for deep indexed information, please consult the subject indexes produced at the end of vol. 15 and at the end of every third volume thereafter through vol. 34/1995, and utilize the search function on the *The Great Lakes Botanist* website for vol. 37/1998 to current.

The index was created using the free citation management software (CMS) Mendeley. The index file exports as an RIS file and can be uploaded into a variety CMS programs, including Zotero, EndNote, and EndNote Web, as well as Mendeley.

Ms. Teghtmeyer can send the file to persons who want it via email (the file is less than 1 MB). To request the file, email Ms. Teghtmeyer at teghtmey@msu.edu and place 'GLB RIS file' in the subject line. We also expect that the file will be available as a download from the Michigan Botanical Club website.

Ms. Teghtmeyer hopes that this index can assist botanical students, researchers, and plant enthusiasts find forgotten articles regarding the flora, botanical publications, and botanists of the Great Lakes region. As a reminder, the full articles are publicly accessible through HathiTrust and our website, https://quod.lib.umich.edu/m/mbot. In addition, the full run of the journal is currently being made available through the publicly available Biodiversity Heritage Library website, www.biodiversitylibrary.org, where volumes 1–18 and 47–57 are currently available.

ISOBEL DICKINSON MEMORIAL AWARD RECIPIENT

Congratulations to **Anna Bowen**, who was the recipient of the Isobel Dickinson Memorial Award for **best student-authored paper** published in the Great Lakes Botanist, Volume 57. The selected paper was "Vascular Flora and Plant Community Types of the Ott Biological Preserve, Calhoun County, Michigan" by Anna K. M. Bowen and J. Dan Skean, Jr., *The Great Lakes Botanist* 57: 100–149. We acknowledge the Dickinson Award Committee for evaluation of the student papers and the Michigan Botanical Club for funding this award.

INSTRUCTIONS TO AUTHORS

Refer to http://quod.lib.umich.edu/m/mbot/submit for more detailed instructions, especially for formatting, style conventions, literature cited, and voucher specimen requirements. Please contact the editor with any questions.

1. Create text in 12-point Times New Roman font and double space paragraphs throughout. Research articles should be organized as follows: Title, Author(s) and address(es), Abstract with up to 5 keywords, Introduction, Materials and Methods, Results, Discussion, Acknowledgements, Literature Cited, Tables, Figure Legends, and Figures. Sections may be omitted if not relevant. All pages should be numbered.

2. For noteworthy collections, manuscripts should be formatted as follows. The title, "Noteworthy Collections," should begin each submitted manuscript, followed on the next line by the State or Province for the species reported. The next line should list the taxon of interest using the following format: Species Author(s) (Family). Common name. The rest of the manuscript should include the following named sections: (i) Significance of the Report, (ii) Previous Knowledge, (iii) Discussion, (iv) Diagnostic Characters (if desired), (v) Specimen Citations, (vi) Acknowledgements (if desired), and (vii) Literature Cited. Each of these sections is largely self-explanatory; however, the "Significance of the Report" section should be limited to a brief sentence or phrase indicating the significance of the collection(s), and this may be expanded upon in the "Discussion" section; the "Specimen Citations" section should include the relevant label data from the voucher specimen(s) including location data, collector(s), collection number, etc., as well as the Index Herbariorum acronym(s) of the herbarium or herbaria where the specimen(s) are deposited. The manuscript should end with the name and address of the author(s).

3. Non-research articles, such as book reviews, letters to the editor, notices, biographies and other general interest articles can be formatted as general text without the specific sections listed above. However, literature cited and any tables or figures should be formatted as described below.

4. Create tables either as an MS Word table or using a tab-delimited format. Each table is to be submitted as a separate file. Table captions should be placed at the top of the table. Any footnotes should appear at the bottom of the table. Please do not insert tables within the body of the text.

5. Send each figure as a separate file in a high-resolution format—eps, jpg, or tif. Figures like bar graphs that gain their meaning with color won't work—use coarse-grained cross-hatching, etc. Create figure legends as a separate text file, and the typesetter will insert them as appropriate. Please do not insert the figure in the body of the text file.

6. Citations: Please verify that all references cited in the text are present in the literature cited section and vice versa. Citations within the text should list the author's last name and publication year (e. g. Smith 1990). For works with more than 2 authors, use "et al.", and separate multiple citations with a semicolon.

7. Literature Cited: List citations alphabetically by author's last name. The first author's name is to be listed with surname first, followed by initials (e.g. Smith, E. B.), and subsequent authors are to be listed with initials first.Separate author's initials with a single space. The year of publication should appear in parentheses immediately before the title of the citation. The entire journal name or book title should be spelled out. Please put a space after the colon when citing volume number and page numbers.

8. Italicize all scientific names. Voucher specimens must be cited in floristic works and in any other study whose results depend on the identity of the plant(s). Papers citing plant records without documenting vouchers are generally not acceptable.

9. Manuscripts must be submitted electronically to the email address of the editor. All manuscripts will be reviewed by at least two referees.

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On the cover: *Flora of the Chicago Region* (upper right) by Gerould Wilhelm and Laura Rericha and several of its predecessors. Photo by Michael Huft.

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